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John J. Gilligan, Governor
DEPARTMENT OF NATURAL RESOURCES
William B. Nye, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Report of Investigations No. 90

SILURIAN ROCK SALT OF OHIO

by

Michael J. Clifford

Columbus

1973

DEPARTMENT OF
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GEOLOGY SERVES OHIO

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SILURIAN ROCK SALT OF OHIO

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ABSTRACT

The salt beds occurring within the Salina Group of the Upper Silurian Cayugan Series underlie the eastern third of Ohio at depths ranging from 1,350 feet in Lorain County to over 6,500 feet in Belmont County. The Salina can be subdivided and individual salt beds identified by means of modern geophysical well logs. The widespread layer-cake nature of the salt beds makes them readily mappable.

The Salina has been subdivided previously into units A through G, in ascending order. Salt is present within the B, D, E, and F units. The F unit contains four salt beds, F_1 through F_4, in ascending order. Thickness of individual salt beds exceeds 50 feet in a few places only, although beds over 100 feet thick have been identified. Greatest aggregate salt thickness is about 250 feet.

The F_1 salt is mined at Fairport Harbor at a depth of about 1,920 feet (Morton Salt Company) and the F_2 at Cleveland at a depth of about 1,760 feet (International Salt Company). These beds, in conjunction with the B, D, E, and possibly F_3 beds, are mined by solution in four artificial brine fields in Ohio. The youngest salt, the F_4, is not mined in Ohio, but three companies produce from it along the Ohio River in West Virginia.

The origin of the Salina salt is uncertain; however, it seems most likely that the beds were deposited subaqueously on the floors of relatively deep basins. Unlike the situation in the Michigan Basin, salt deposition in Ohio seems to have been unrelated to Niagaran reefs.

In the early 1800's, Ohio was a leading producer of salt from naturally occurring shallow brines, but the industry withered until the discovery of the Salina salt in 1889. Growth was rapid thereafter. Over six million tons of salt worth over fifty million dollars a year are produced from two mines and four brine fields in Ohio. Rock salt from the mines is used primarily for road deicing. Evaporated salt for the food industry is the main product of the Morton Salt Company (Rittman) and Diamond Crystal Salt Company (Akron) brine fields. Brine from the Diamond Shamrock Corporation field at Painesville and the PPG Industries, Inc., field at Barberton supplies the chlor-alkali industries.

Salt reserves are in excess of two and a half trillion tons. Ohio, with its favorable location in respect to industry and transportation, will be a leading salt producer for the foreseeable future.

INTRODUCTION

The Silurian rock salt underlying eastern Ohio is an important economic resource. Presently there are two mines and four artificial brine fields utilizing these beds to produce rock salt and brine valued at over fifty million dollars per year.

The last detailed statewide study of these strata was by Pepper in 1947. In the intervening 25 years much additional information has become available from cores and geophysical well logs. The purpose of this report is to incorporate this new information into a detailed description of the salt of Ohio. The first part of the report concerns the geology of the salt; it includes stratigraphy, thickness, origin, and distribution of the beds. The second part covers historical and present industrial usage of the salt.

ACKNOWLEDGMENTS

Thanks to Don Richner of Terraneers, Ltd., for introducing the writer to some of the methods and problems of the salt industry. Information and/or materials were kindly supplied by Morton Salt Company, International Salt Company, East Ohio Gas Company, Columbia Gas System, and PPG Industries, Inc.

GEOLOGY OF THE SALT BEDS

GENERAL GEOLOGY

The salt beds in Ohio are situated within the Salina Group of the Upper Silurian Cayugan Series. The group consists of interbedded dolomites, anhydrites, shales, and salt and is widespread in the subsurface of the Michigan and Appalachian Basins. Salina rocks were deposited during a period of about one and a half million years, beginning about 410 million years ago (Rickard, 1969).

The Salina Group underlies all of Ohio except for the southwestern portion and areas along the Cincinnati arch; however, the salt beds are restricted to the eastern third of the state. Figure 1 shows the generalized distribution and total thickness of the salt beds within the Salina. The salt-bearing beds dip to the southeast about one-third degree (30 feet per mile)

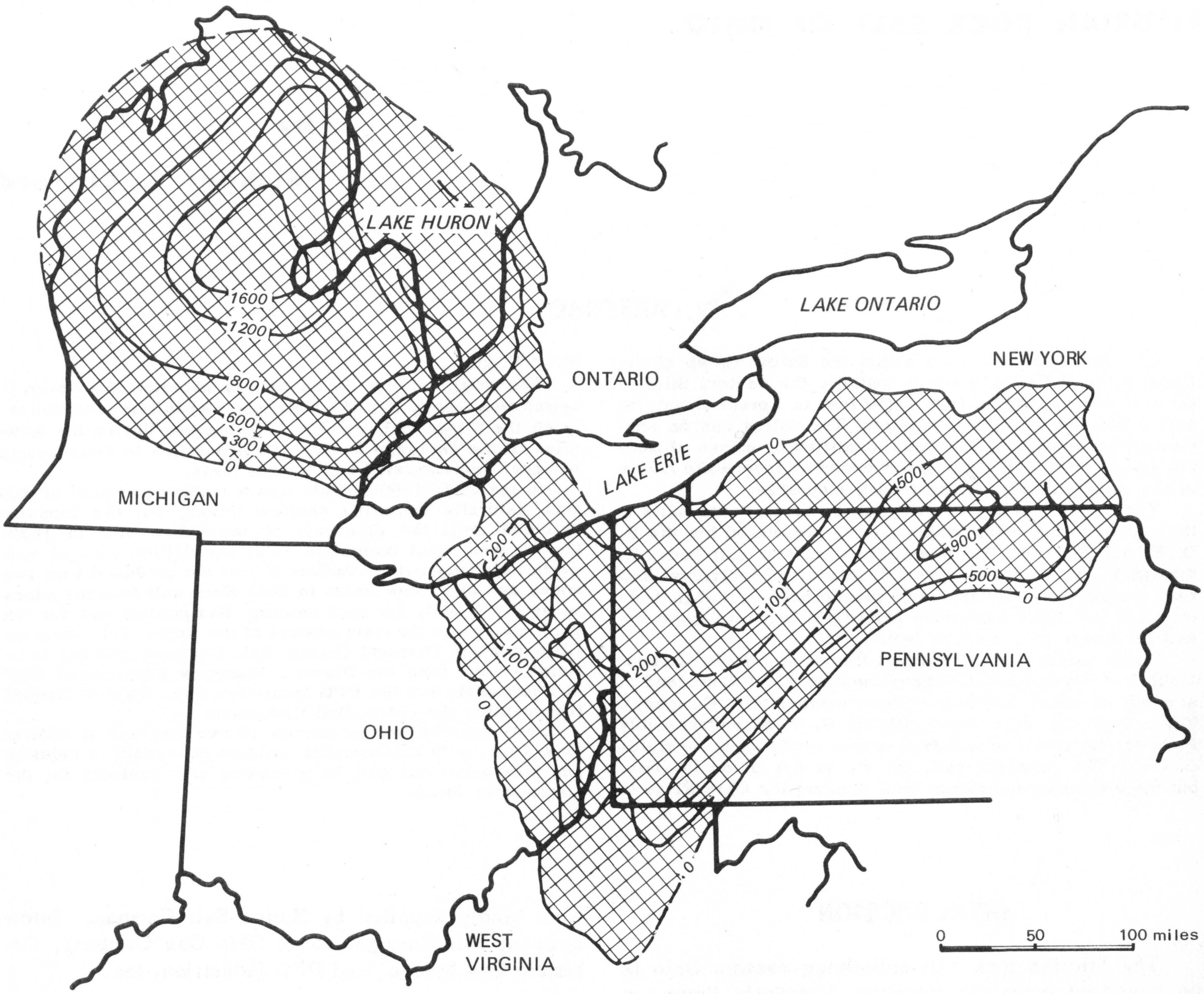

FIGURE 1.—Generalized distribution and thickness of Salina salt beds (modified in part from Fergusson and Prather, 1968; Griggs, 1958; Sanford, 1965; and Rickard, 1969).

from Lorain County to Stark County, steadily increasing to almost one degree (80 feet per mile) in Monroe and Belmont Counties. Depth to the top of the salt increases from about 1,350 feet in Lorain County to over 6,500 feet in Belmont County (fig. 2).

PREVIOUS WORK

The first significant work dealing with the Salina salt in Ohio was done in 1947 by Pepper, who mapped the distribution and total thickness of the Cayugan salt, using data from well samples and drillers' logs. With the limited information available at the time, he was quite successful in outlining the Ohio portion of the Appalachian salt basin.

Alling and Briggs in 1961, in a regional stratigraphic analysis of the Cayugan rocks, showed that the sequences of evaporites in the Michigan and Appalachian Basins were lithologically similar and occupied the same stratigraphic position. These authors recognized that surface exposures lithologically were not representative of the subsurface section, and that surface nomenclature is difficult to apply. They were able to trace the Michigan Basin subsurface units previously proposed by Landes (1945) into Ohio and farther east; their belief was that the salts were deposited in basins isolated from the ocean by encircling reefs. This concept of bounding reefs is discussed in a later section; especially as applied to Ohio, it has not stood the test of time. The work of Alling and Briggs was valuable chiefly in showing that the Cayugan strata of both basins could best be understood by treating

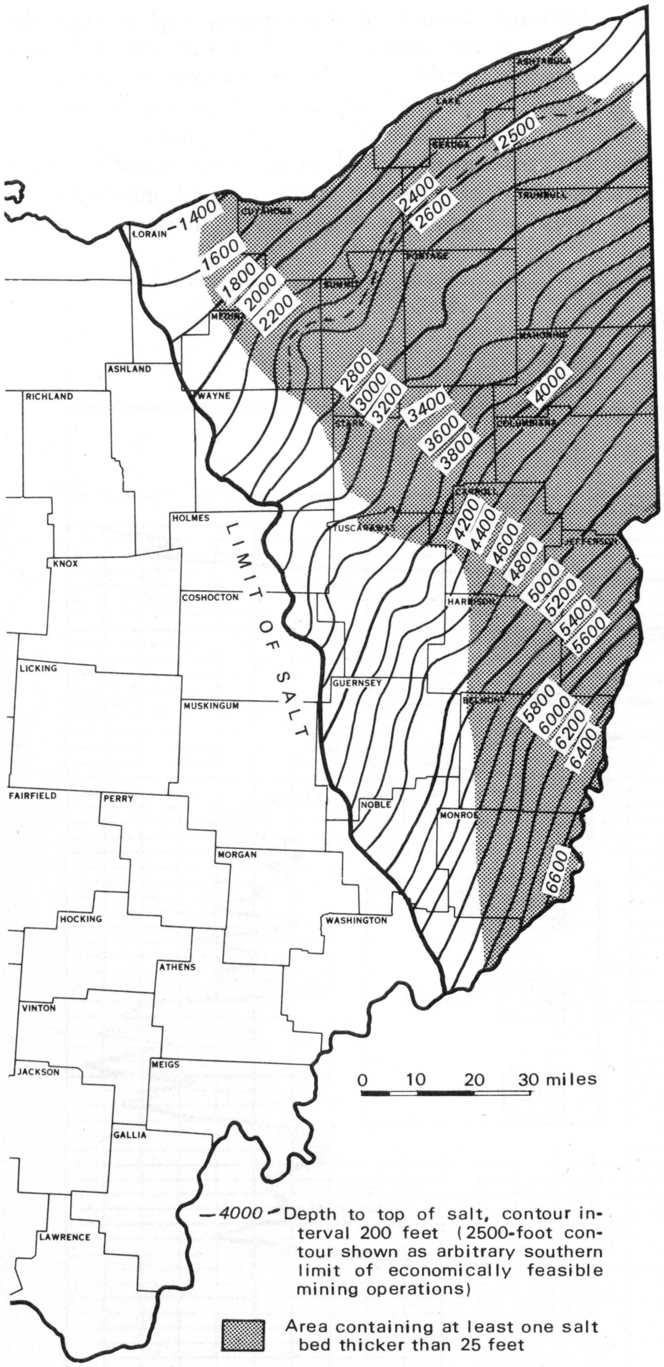

FIGURE 2.—Depth to top of salt; contours have no structural significance.

them as an interrelated whole.

In 1963, Stehli, Namy, and Aten used geophysical logs to subdivide the Cayugan in northeastern Ohio. They numbered the salt beds and grouped them into four "salt zones." They then prepared a series of isopach and structure maps showing areas of economic potential. Their work stressed also the deep-basin origin of the salt.

A major paper relating the Salina in Ohio to the rock sequence in the Michigan Basin was published by Ulteig in 1964. This important study not only introduced the present subsurface terminology for the Salina in Ohio, but is an excellent stratigraphic study of the Salina as well. On the basis of well samples and 118 geophysical logs, Ulteig described and defined the Salina units in the northeastern quarter of Ohio and constructed a series of structure and isopach maps of the various Cayugan units; in addition, he prepared numerous cross sections. Ulteig's nomenclature was slightly modified from that used by Ells in 1962 so that the unit boundaries correspond to the most distinctive widely traceable units recognized on gamma ray geophysical logs in Ohio and adjacent areas. Ulteig recognized also the previously undocumented magnitude of the Silurian/Devonian unconformity in the subsurface of Ohio. He did not treat the salt beds other than to show the general distribution of the salt.

Oinonen, in an unpublished 1965 master's thesis, prepared isopachs of several salt units in northeastern Ohio. He used both electric logs and core descriptions for control and applied Ulteig's nomenclatural designations.

Jacoby in 1969 prepared a cross section demonstrating the equivalence of the B unit of the Salina in New York and in Ohio and stressed the usefulness of geophysical logs in Salina studies.

Rickard in 1969 related the Salina rocks of the Appalachian Basin of New York, Pennsylvania, Ontario, West Virginia, and Ohio to one another and showed that the Michigan Basin terminology was applicable throughout the area. His study contributes much to the knowledge of the regional aspects of Salina stratigraphy, especially on the eastern flank of the Appalachian Basin. Included in his report are general isopachs of the salt thickness and a discussion of the salt origin; he apparently used Ulteig's data for Ohio.

PRESENT STUDY

This report utilizes a wealth of subsurface data available from modern geophysical logs. Geophysical well logging was introduced to the Appalachian area in the 1940's. In the 1940's and 1950's the gamma ray-neutron log was the primary logging tool. This log provides traces which enable the subsurface worker to subdivide and correlate the various units; however, without supporting evidence this type of log is not directly useful for identifying salt beds. In the early 1960's the density log became available. This log, in combination with gamma ray and caliper logs, makes salt bed detection accurate and routine, but borehole roughness sometimes hinders interpretation. By the mid-1960's, an improved density log, which was compensated for borehole irregularities, was available. With this device it is possible to identify salts with an accuracy comparable to that possible from core descriptions. Figure 3 is a comparison between the Schlumberger Compensated Formation Density Log and the description of the core from a well in Tuscarawas County. The excellent correlation between the two is apparent. From a well-prepared density log it is in many cases possible to delineate within the salt bed streaks of anhydrite or dolomite as thin as one foot.

An additional benefit of the density log is that the lithologies of the rocks associated with the salt may commonly be identified by a comparison of the grain densities. Gamma ray and caliper logs are almost always run with the density log. The gamma ray log is used for correlation and as an aid in lithologic identification. The caliper log gives a good indication of salt beds because the borehole is always enlarged

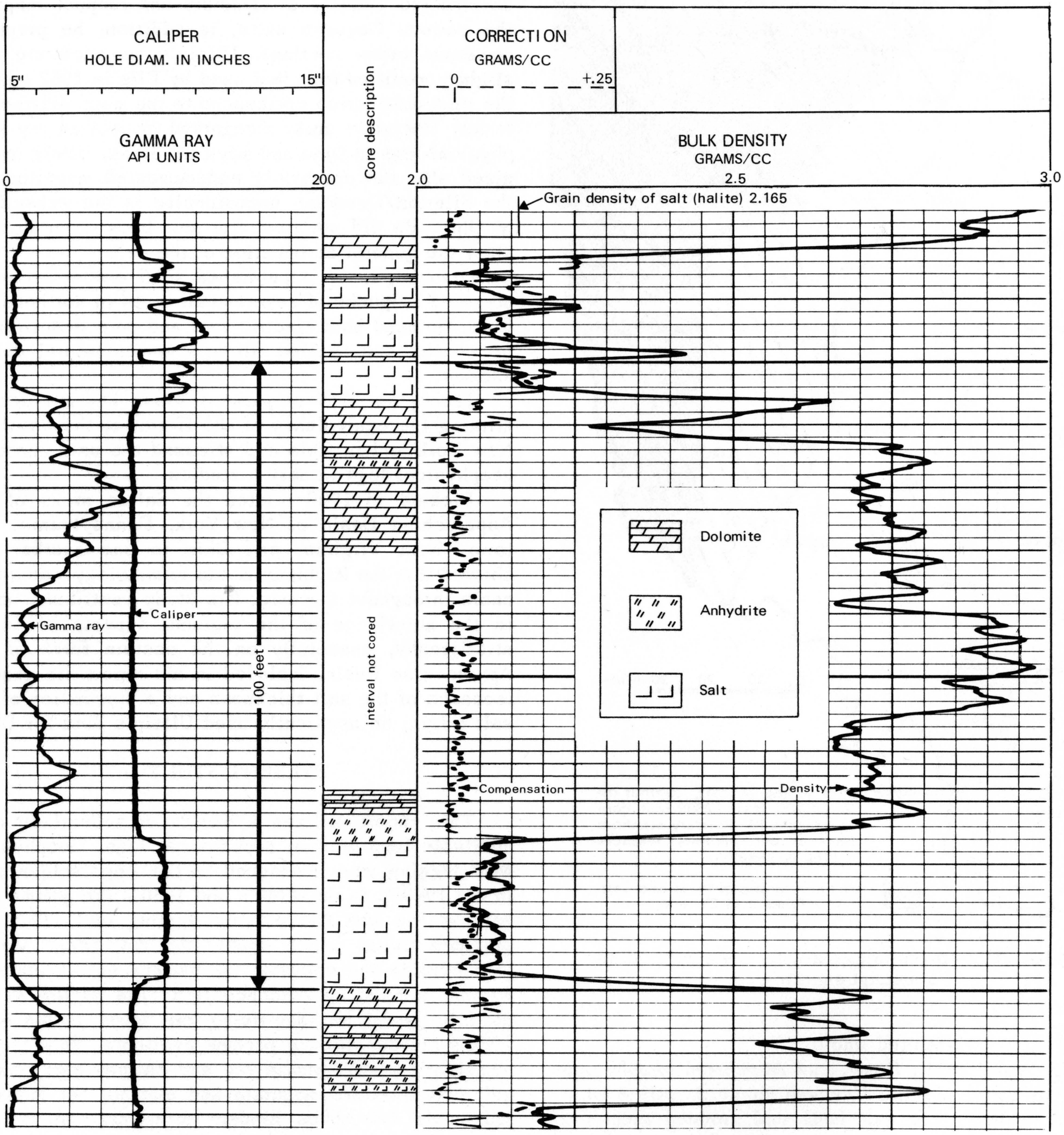

FIGURE 3.–Comparison between Compensated Formation Density Log and description of the core from a well in Tuscarawas County, Ohio.

through the salt section in fluid-filled holes and is generally enlarged in air-drilled holes. Density logs are the basis of most of the salt-thickness determinations in this report. Sonic, microlog, and resistivity logs were used in a few cases to identify salt where density logs were not available. A Schlumberger Limited document (1969) gives explanations of the function and methods of interpretation of the various logs.

Core descriptions were available for a few wells in the study area. Appendix A is a compilation of the cores and core descriptions available at the Ohio Division of Geological Survey. Well samples and well sample descriptions were found not to be generally useful in this study and were used only in a few remote areas. Samples and sample descriptions rarely reflect the true thickness of the salt. Most wells are drilled using water not saturated with respect to salt, so that many feet of salt must be penetrated before the fluid becomes saturated and is able to carry rock salt to the surface. Even then, careless sample washing generally removes the salt, rendering the samples useless for salt determination. On the other hand, some sample and drillers' logs vastly overestimate the salt by reporting the entire interval between first and last occurrence of salt as a single salt bed. As an example of this problem, one report based on drillers' logs (Gambs and White, 1946, p. 15) listed salt thicknesses ranging from 30 feet to 450 feet within a single township of Harrison County. Sufficient control is now available to show that a more reasonable range is about 35 feet to 80 feet. It can be seen that well sample information should be used with great discretion, if at all, in a study of this sort.

Experience has shown that, except for a slight regional thickening of the Salina units eastward, changes in the thickness of named units can in almost every case be attributed only to the presence of more or less salt in the section. The same situation has been noted by Evans (1950) in the Michigan Basin and Rickard (1969) in the eastern Appalachian Basin. This relationship is especially clear on cross section A-A' (pl. 1). Note, for example, the eastward thickening between P-447 and P-410 with the addition of the F_2 and F_3 salts or the section added where the F_1 salt is present in P-859 (compare P-908). Many other examples can be seen both on this cross section and on cross section B-B' (pl. 1). Because of this relationship it is possible to gain some useful salt thickness information from gamma ray logs. By comparing thicknesses within a given interval with density logs from nearby wells in which salt thickness is known, it is possible to see section added or missing. The difference represents change in salt thickness. This usage of gamma ray logs greatly extends the control available to the subsurface worker.

Data sheets were prepared (appendix B) listing the tops of the Salina units and thickness of salt within the units; control was from about 450 geophysical logs and selected sample and core descriptions. Two structure maps (pls. 2, 3) and seven isopach maps (pl. 4) were prepared.

STRATIGRAPHY

General statement

The present subdivision of the evaporite-bearing[1] rocks of eastern Ohio is based strictly on gamma ray geophysical log response. Much of the Salina lithology is difficult to describe from well samples. The rock is grayish-brown dolomitic anhydrite, dusty on weathered surfaces, with a dull luster on fresh breaks, and with a fine-silt-size granular texture. There appears to be a high clay content under binocular examination, but selected samples examined by x-ray methods have shown little clay. Various investigators have recorded this unusual lithology as dolomite, anhydrite, or even shale. This difficulty in describing the Salina beds consistently, coupled with the problem of recovering salt in well samples, prevented the practical lithologic subdivision of the Salina in the Appalachian Basin prior to the advent of geophysical logs and led early workers to conclude that the Salina salts were discontinuous and distributed in an erratic fashion. As late as 1960, Deutsch (p. 148), referring to the salt deposits of Ohio and eastern New York, stated:

> A string of ten wells, stretched out about a mile ... may pierce several different strata which never interconnect. A true and complete knowledge of the salt stratigraphy is rarely entirely in hand. The investor in brine wells should always be keenly aware that his favorite salt stratum can pinch out anywhere around the periphery of his field as well as in the middle of it.

The evidence now available shows that the Salina rocks, including the salt beds, are persistent and blanket deposits in large areas. Cross section B-B' (pl. 1) traces the Salina Group and its subdivisions across eastern Ohio from Ashtabula County to Muskingum County, a distance of about 130 miles. Rickard (1969, pl. 11) has traced the same units from New York to the Michigan Basin, over 400 miles; the rocks may be easily correlated an additional 200 miles or so across that basin. Single salt beds also carry for long dis-

[1]Throughout this report the term "evaporite" is used in the conventional lithologic sense to refer to halite, anhydrite, and the finely crystalline species of dolomite commonly called "evaporite-dolomite." The term "evaporite" may carry the connotation of deposition in shallow water, or evaporation to dryness, or even supratidal conditions. The author believes the Cayugan evaporites to have been deposited on the floors of relatively deep basins by a precipitation process and only indirectly as a result of evaporation. In the absence of a widely accepted substitute word for "evaporite," however, the term is used without any connotation of shallow-water conditions.

tances. For example the D salt (Rickard, pl. 12) seems to extend for over 270 miles. In Ohio, using close well control, several salt beds are shown to be continuous over areas of at least 500 square miles and easily as much as 5,000 square miles of area with less dense control.

The stratigraphic subdivisions of the Salina used in this report are not strictly defined formations or members according to usage of the American Commission on Stratigraphic Nomenclature (1970), but are instead the rocks occurring between key beds that are geophysical log markers. Units thus defined are not dependent upon lithology, although they generally do have characteristic lithologies. In subsurface work, such units, termed "formats" by Forgotson (1957), are in most cases more objective and more useful than the formal units sanctioned by the Commission. As Krumbein and Sloss (1963, p. 338) point out,

> ... the key beds and the bodies of strata they enclose are among the most useful of stratigraphic horizons and units available for subsurface studies of structure, thickness variations, and facies and ... are applicable to time-stratigraphic correlation.

The log markers defining the Salina units of this report coincide essentially with those used by Ulteig (1964); his are based on those used in the Michigan Basin. The original subdivision of the Salina in the Michigan Basin was derived in 1945 by Landes, who established units A through H on the basis of well-sample lithology. When geophysical logs became available, the units were redefined by Evans (1950) and Ells (1962) to coincide with log markers in order to provide greater objectivity and utility for subsurface stratigraphy. The Salina units currently used in the Michigan Basin are defined by Ells (1967, p. 5) strictly on the basis of geophysical log markers.

The relationships between the Salina units used in this and in previous reports are shown in figure 4. The composite section used for comparison is modified from Ulteig. Note in this figure the numbered units proposed by Stehli and others (1963) to subdivide the Salina. Although these units did not gain wide acceptance, it is a tribute to the stratigraphic utility of geophysical logs that the corresponding gamma ray log deflections were chosen independently as mappable boundaries.

Salina units

A unit.—The A unit, the basal Salina unit, does not contain salt in Ohio or elsewhere in the Appalachian Basin. The unit thickens markedly into the Michigan Basin, where hundreds of feet of salt are present.

The top of the A unit is a reliable marker throughout most of eastern Ohio, but becomes less reliable south and west of Guernsey County. A structure map was prepared on this horizon (pl. 2).

B unit.—Ulteig (1964) describes the B unit as varying from "interbedded salt and shale in Lake County to argillaceous, anhydritic dolomite or lutite in the western part of the study area." He placed the lower limit of the B unit at the base of a twin-peaked log character (fig. 4) caused by two anhydrites separated by a thin shale bed. In the northern part of the study area the base of the unit is placed at the base of the lowest salt overlying the A unit. Thickness of the B unit ranges from about 150 feet in the north to 65 feet in Muskingum County.

The salts of the B unit tend to be multiple, thin-bedded, and impure. The thickest single bed rarely exceeds 10 feet in Ohio, although the highest B salt bed attains a thickness of about 20 feet in New York where it is mined at Retsof Mine south of Rochester. In Ohio, the B salt is mined only by solution and in conjunction with higher beds.

Distribution and thickness of the total B salt is given in plate 4. Maximum net salt thickness is just over 100 feet in northern Lake County, with uneven thinning southward. Data from Sanford (1965) and Rickard (1969) suggest that the B salt beds may be continuous across Lake Erie. If so, they are the only salts that are, although several anhydrite beds probably continue across the lake.

The rugged line marking the southern limit of the B salt probably results in part from subaqueous erosion or re-solution and in part from depositional thinning over topographic irregularities resulting from Lockport reefs. The irregular pinchout in northern Ashtabula County, on the other hand, may result from much later solution of the salt beds, producing collapse of overlying beds. The B salt is absent in well P-90, Conneaut Township, yet is present less than a mile and a half to the north in well P-167. The first well is 86 feet lower than the second at the top of the A unit and 118 feet lower at G-unit level, the difference being about equal to the amount of salt which by regional considerations seems to be missing. A similar situation in Pierce Field, located just a few miles to the east in Erie County, Pennsylvania, has been interpreted by Kelley and McGlade (1969) as evidence for solution collapse.

C unit.—The C unit is the most distinctive of the Salina subdivisions and the most easily traceable throughout the Michigan and Appalachian Basins. The rock type, described by Ulteig as a gray to green anhydritic and dolomitic shale, gives a typically high gamma ray radiation response. The unit contains no widespread bedded salt, but in a few places red salt is present, filling fractures and veins.

In Ulteig's study, the base of the C unit was chosen at a log deflection marking the top of an anhydrite within a 100-foot-thick shale sequence. Although this marker is indeed generally traceable in northeastern Ohio, it disappears southward and westward; moving the base of the C unit down to the base of the shale-like gamma ray character makes the unit more widely mappable. The redefinition makes the Ohio terminology

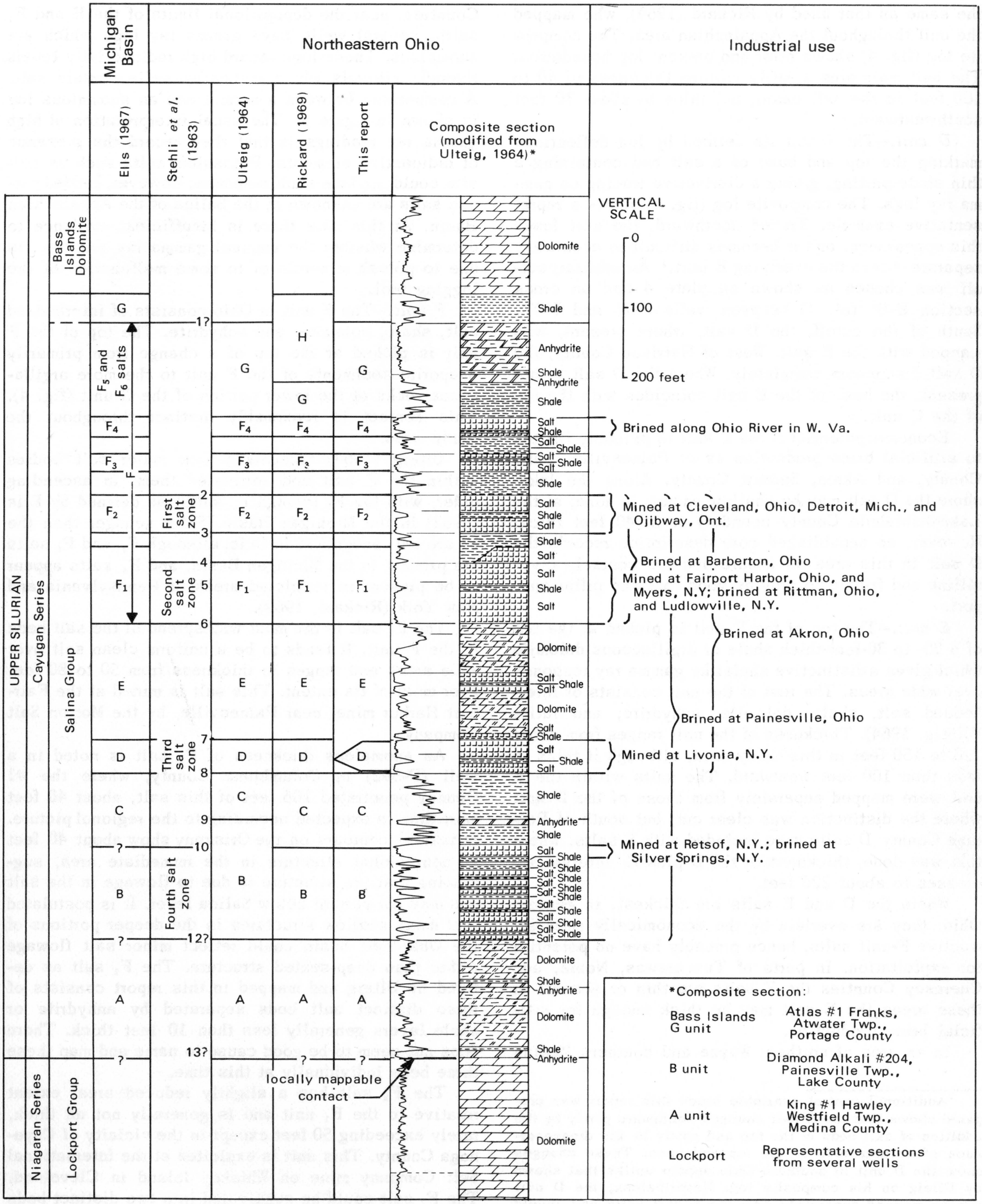

FIGURE 4.—Composite section showing Salina units used in this and previous reports and indicating industrial usage.

the same as that used by Rickard (1969), who mapped the unit throughout the Appalachian area. The composite log (fig. 4) shows prior and present log boundaries. The unit maintains a fairly uniform thickness of 60 to 100 feet in the salt basin, but thins to about 30 feet southwestward.

D unit.—The D unit is defined by log deflections marking the top and base of a salt bed containing a thin shale parting, giving a distinctive tracing on gamma ray logs. The composite log (fig. 4) shows a representative example. Traced southward, the unit loses this appearance, and it becomes difficult to accurately separate it from the overlying E unit.[2] An arbitrary cutoff was chosen as shown on plate 4 and on cross section B-B' (pl. 1) between wells P-76 and P-77. South of the cutoff, the D salt, where present, was mapped with the E salt. West of Harrison County, the D salt disappears completely. Where the D salt is not present, the base of the E unit coincides with the top of the C unit.

Economic potential of the D salt is probably limited to artificial brine production as at Painesville, Lake County, and Akron, Summit County. Along the lakeshore the D salt may be shallow enough to mine; at the Lake-Ashtabula County boundary it is 40 feet thick. However, an unpublished core description records the D salt in this area as impure and too coarsely crystalline and friable to provide good roof and pillar support.

E unit.—The top of the E unit is picked at the top of a 20- to 30-foot-thick shale or argillaceous dolomite which gives a distinctive shalelike gamma ray response over wide areas. The rest of the unit consists of interbedded salt, shale, dolomite, anhydrite, and lutite (Ulteig, 1964). Thickness of the unit ranges from about 120 to 150 feet in this study area, although it thins to less than 100 feet westward. The salts within the E unit were mapped separately from those of the D unit where the distinction was clear cut, but south of Portage County D salts were included with E salts. Where this was done, thickness of the D plus E interval increases to about 220 feet.

Where the D and E salts are thickest, in eastern Ohio, they are overlain by the economically more attractive F-unit salts, hence probably have no potential for exploitation. In parts of Tuscarawas, Noble, and Guernsey Counties the F salts are thin or absent; in these areas the E salt may be thick enough for artificial brine production.

In an area of northern Wayne and southern Medina Counties, near the depositional limits of the E and F_1 salts, several wells have gamma ray logs which are anomalous. These logs record high radioactivity levels through intervals which in nearby wells contain salt. A comparison between a normal and an anomalous log is shown in figure 5. The usual interpretation of high gamma ray readings is that they record the presence of radioactive elements. Potassium salts such as sylvite could produce such response; however, bedded potash salts are unknown in the Salina of the Appalachian Basin. At this time there is insufficient evidence to determine whether the unusual gamma ray response is due to potash minerals or to some malfunction of the logging tool.

F unit.—The F unit in Ohio consists of interbedded salt, shale, dolomite, and anhydrite. The top of the F unit is picked at the top of a change from primarily evaporite sediments of the F unit to the more argillaceous rocks of the lower portion of the G unit (fig. 4). This contact is reasonably distinct throughout the study area.

Ulteig (1964) recognized four major salt bodies within the F unit and correlated them, in ascending order, with the F_1 through F_4 salts, as defined by Ells (1962) in the Michigan Basin. Salts younger than the F_4 are not recognized in Ohio, although F_5 and F_6 salts are present in the Michigan Basin, and F_5 salts appear to be present in restricted areas of Pennsylvania and New York (Rickard, 1969).

The F_1 salt is the most widespread of the salt beds in the F unit. It tends to be a uniform clean salt over wide areas and ranges in thickness from 50 to 80 feet over most of its extent. This salt is mined at the Fairport Harbor mine, near Painesville, by the Morton Salt Company.

An anomalous thickness of F_1 salt is noted in a well (P-592) in Columbiana County, where the #1 Denney penetrated 106 feet of this salt, about 40 feet more than is expected according to the regional picture. Structural contours on the Oriskany show about 40 feet of nonregional structure in the immediate area, suggesting that the structure is due to flowage in the salt and may not persist below Salina level. It is postulated that many shallow structures in the deeper portions of the Ohio salt basin could reflect minor salt flowage rather than deep-seated structure. The F_1 salt as defined by Ulteig and mapped in this report consists of three distinct salt beds separated by anhydrite or shale layers generally less than 10 feet thick. There does not seem to be good cause to name and map these three beds individually at this time.

The F_2 salt has a slightly reduced areal extent relative to the F_1 unit and is generally not as thick, rarely exceeding 50 feet except in the vicinity of Cuyahoga County. This unit is exploited at the International Salt Company mine on Whiskey Island in Cleveland. The F_2 salt could be subdivided into two distinct beds that could be mapped individually.

[2]Additional control available since this report was prepared shows that the D salt changes southward partly by the addition of salt beds at the top and partly by the disappearance of certain beds at the top and base. These changes make the D unit in southern Ohio appear unlike that shown by Ulteig on his composite log. Nevertheless, the D unit can be mapped separately from the E unit salts and should have been so treated.

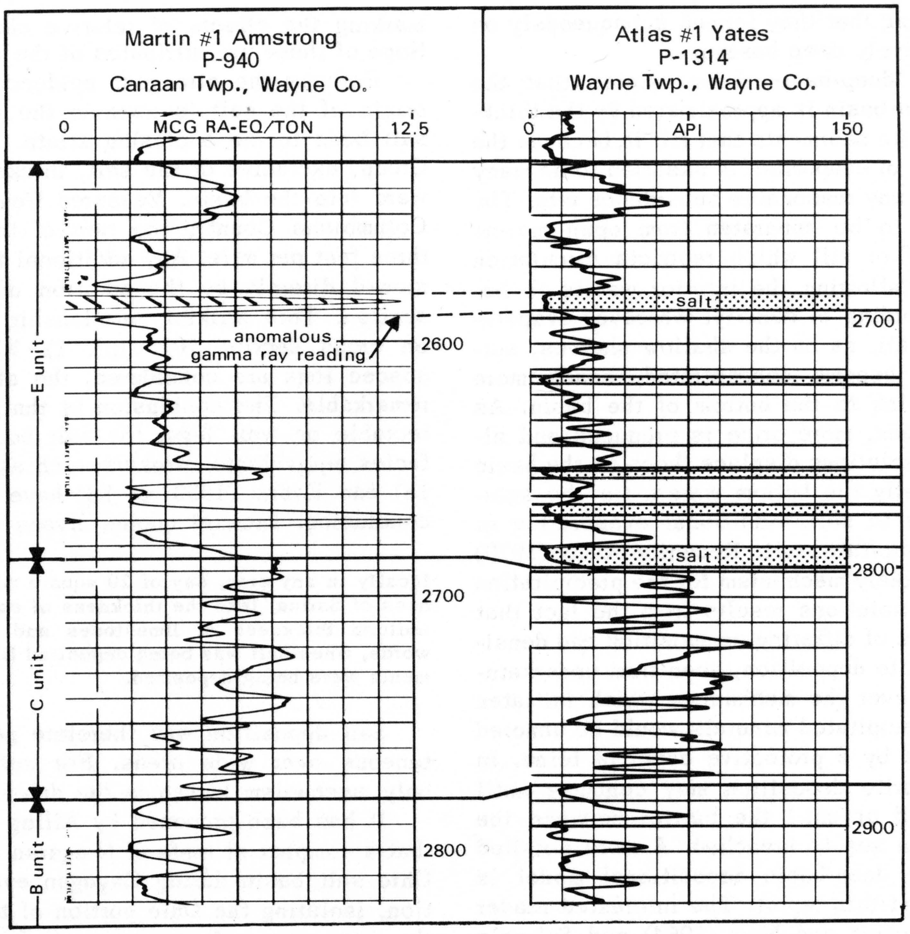

FIGURE 5.—Comparison between normal and anomalous gamma ray logs, Wayne County, Ohio.

The thinner F_3 salt appears to have no commercial importance. It reaches its maximum thickness of 31 feet in Mahoning County, but over most of the area is less than 20 feet thick.

Of greater importance economically is the F_4 salt, which is absent in Tuscarawas County, but thickens rapidly to a maximum recorded thickness of 127 feet at the Natrium brine field operated by PPG Industries, Inc., in Marshall County, West Virginia. The greatest thickness of this salt seems to be confined to a rather narrow trough along the Ohio River. Other artificial brine fields producing from this salt are operated by F.M.C. Corporation at Bens Run, Tyler and Pleasants Counties, and by Allied Chemical Corporation-Solvay, at Round Bottom, Marshall County, West Virginia. Producing depths are as much as 6,800 feet at the Natrium plant.

G unit.—The uppermost unit of the Salina is the G unit, which is capped by a thick anhydrite ranging from 30 feet in Lorain County to 100 feet in Hancock County, West Virginia. Below the anhydrite is a 50-foot dominantly shale section, which is underlain by the more anhydritic F section, as indicated by the composite log. The top of the G unit is the uppermost anhydrite in the Silurian section and is a good marker in samples as well as an excellent log marker. A structure map (pl. 3) prepared on this horizon may be used to predict top of salt when used in conjunction with ground elevation and with intervals from nearby logs.

ORIGIN AND DEPOSITIONAL FRAMEWORK OF SALINA SALT

The origin of thick laterally extensive salt deposits such as the Salina is not positively known because there does not appear to be a modern analog. Present marine halite deposition is confined to shallow local barred lagoons. Minor quantities of halite are forming in supratidal zones in extremely arid regions. Neither process, however, seems to explain the major salt deposits. Most authors (Rickard, 1969; Alling and Briggs, 1961; Matthews, 1970; Schmalz, 1969; Stehli, Namy, and Aten, 1963) have concluded that the great thicknesses, extreme lateral extent, essentially nonclastic and nonfossiliferous sediments, and layer-cake stratigraphy of the Salina salt beds can best be explained by assuming that they formed subaqueously on the floors of relatively deep basins.

In brief, this deep-basin theory states that the original depth of the basin is approximated by the thickness of the evaporite sediments that fill it, because the sedimentation rate of evaporites is assumed to be many times greater than any reasonable subsidence rate. The basin is thought to be separated from open marine waters by a shelf or sill which restricts circulation within the basin, allowing the interior waters to become layered according to density. Wherever evaporation exceeds rainfall, as on the shallow shelves, surface waters will become concentrated, hence more dense, and will sink to the bottom of the basin. As evaporation proceeds, more brine is produced and always the densest solutions displace those on the basin floor until eventually the bottom waters may be saturated with respect to salt. Additional evaporation or cooling could precipitate salt. Recently Raup (1970) has shown that a likely mechanism for the precipitation of salt from such solutions results from the fact that the mixing of brines of differing composition and density may initiate halite deposition, even from undersaturated brines. Whatever the mechanism which initiates deposition, any precipitated minerals would be armored against re-solution by a protective cover of brine. In this manner evaporite deposition may continue until the basin is filled or until the barrier between the basin and the open sea is breached. A more detailed description of the deep-basin depositional model is beyond the scope of this report. The interested reader is referred to Borchert and Muir (1964) and Schmalz (1969) for additional discussion. It should be made clear that the "deep-basin" name for this theory refers more to the density-layering mechanism than to water depth. The model could operate in any water depth from very deep (hundreds of feet) to almost wave base.

Estimates of water depth during Salina deposition vary. Schmalz's model implies a depth of at least 600 feet for much of the Ohio portion of the basin at the beginning of Salina time. Rickard (1969) has calculated water depths based on assumed sedimentation rates versus subsidence rates and has concluded (p. 22) that: ". . . most of the Salina evaporites were deposited in waters 100 to 400 feet and possibly as much as 600 feet in depth." Dellwig and Evans (1969) believe, however, that the presence of ripple marks and absence of laminations in the salt beds exposed in the Ohio mines indicate much shallower depositional conditions.

The widespread layer-cake geometry of the Salina, implying the presence of an extensive basin, is a strong argument for simultaneous deposition of any given unit over a wide area. The only other geologically reasonable method by which such units could be formed is by a series of transgressions and regressions. If this were the case, the rock record should contain multiple unconformities, clastic deposition, alternating marine and terrestrial sediments, and fossiliferous zones marking the effects of relative change in sea level. None of these are attributes of the basinal Salina.

Perhaps the strongest evidence for a deep-basin origin of the salt is seen in the relationship of the salt beds to the enclosing strata. In Ohio the Salina Group, exclusive of the salt, thickens gradually eastward into the basin. Measured from Wayne County to Columbiana County, the rate of thickening is about three feet per mile. Any additional thickening is occasioned directly by the addition of salt beds to the section. This striking relationship is well displayed on cross section B-B' (pl. 1). Where more closely spaced logs are considered, the effect is even more remarkable. The conclusion is that, on the scale detectable on well logs, the salt beds have no lateral facies equivalents. Workers such as Rickard (1969, p. 18) and Evans (1950, p. 58) have reached the same conclusion. Rickard quotes Evans to the effect that:

> locally in any area, say of 20 square miles, the total thickness of Salina, less the thickness of salt, will give a fairly uniform thickness of limestones and dolomites. In other words, when salt was being deposited little or no other sediments were being deposited.

Salt deposition was therefore geologically instantaneous over wide areas. For such deposition, the only mechanism known is the density-layered system.

It has been proposed by Alling and Briggs (1961) that a complex of reefs of Niagaran age surrounded the Ohio salt basin during Cayugan evaporite sedimentation, isolating the Ohio portion of the salt basin from the open sea and separating it from the rest of the Appalachian Basin. The reefs were said to form "the ultimate control of subsequent evaporite deposition." Following Alling and Briggs, Cate (1963, p. 23) also referred to this barrier area.

This author was unable to find any evidence of a reef complex separating Ohio from the Appalachian Basin; neither is there any evidence that reefs anywhere in Ohio had a demonstrable effect in creating the conditions leading to evaporite deposition. There would have to have been considerable difference in thickness between the Lockport (Niagaran) in the salt basin and in barrier areas in order that over 800 feet of chiefly evaporite sediments could be deposited in the nonreef area while the barrier retained topographic expression. It follows also that for reefs to control the sedimentation, they themselves could not have been buried by such sedimentation. To the author's knowledge, all wells drilled to date in eastern Ohio have A-unit (early Cayugan) strata overlying the Lockport Formation. In central Ohio, where the section has not been eroded, all wells have penetrated B-unit strata overlying the Lockport and, with a few possible exceptions, all have A-unit strata also. In south-central Ohio, there may be areas where the A and B units are missing because of nondeposition, but these areas are not associated with thick Lockport sequences.

The areas in which Alling and Briggs propose that Niagaran reefs controlled Cayugan sedimentation are compared with total salt thickness (fig. 6) and with thickness of the Lockport Formation (fig. 7). It is apparent from these maps that Niagaran reefs could not have been responsible for Cayugan sedimentation, at least within the areas shown.

Concerning the barrier reef hypothesis for the origin of the Appalachian salts, Rickard (1969, p. 23) writes:

> Except for those along its common border with the Michigan basin, no reefs are known around the margins of the Appalachian basin. Much of the eastern border of this basin was a land mass whose erosion supplied the sediments of the Bloomsburg delta. This land may have persisted throughout all of Salina time effectively separating the Salina Sea

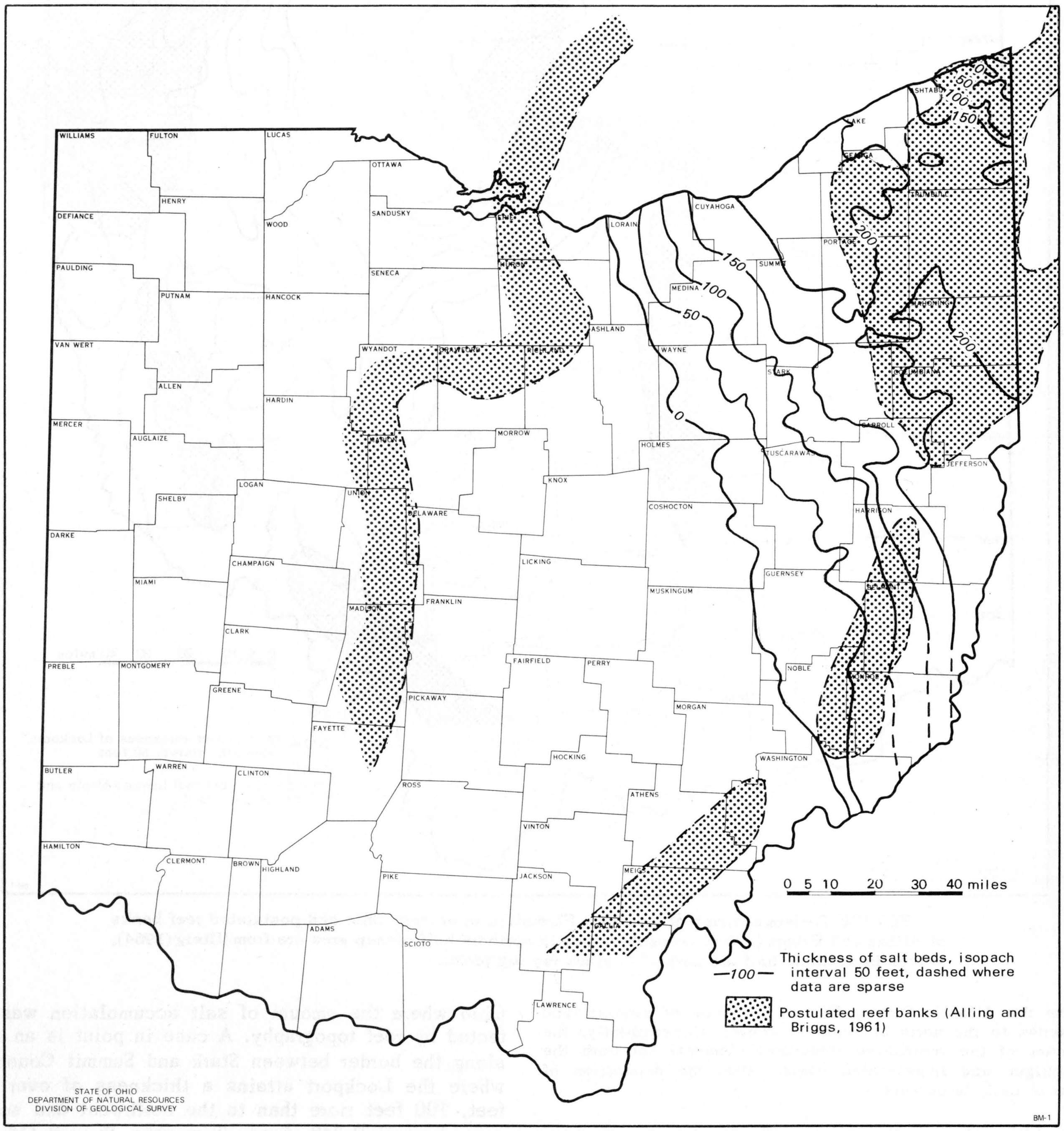

FIGURE 6.—Isopach map of Salina salt beds and postulated reef banks of Alling and Briggs (1961).

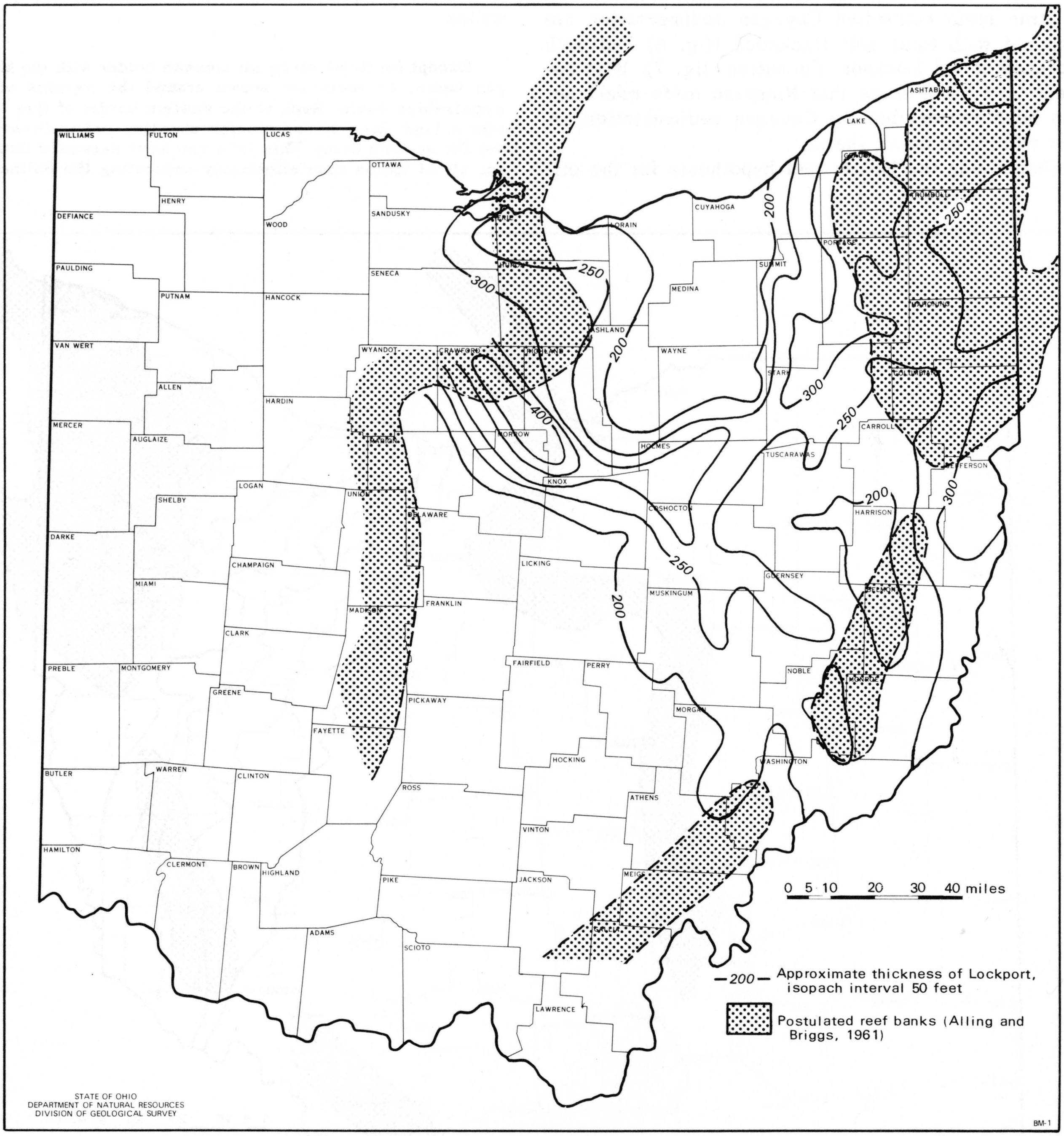

FIGURE 7.—Isopach map of Lockport Formation in eastern Ohio and postulated reef banks of Alling and Briggs (1961). Isopach values in northern half of map area are from Ulteig (1964); values in southern half are author's gamma ray log picks.

from the Atlantic Ocean. But no evidence of similar land masses to the north or south is known. Consequently, the nature of the restrictive structural elements for both the Michigan and Appalachian basins after the deposition of [the A unit] is uncertain.

Although the Niagaran reefs in the Appalachian area apparently had no cause-and-effect relationship with evaporite deposition, there were some areas in Ohio where the amount of salt accumulation was affected by reef topography. A case in point is an area along the border between Stark and Summit Counties, where the Lockport attains a thickness of over 300 feet, 100 feet more than to the northwest and southeast. In well P-348, Green Township, Summit County, thinning of the Cayugan section is noted as high as the F unit. Thinning appears to be most marked in the salts. This effect seems to support the idea that the sediments were deposited as a precipitate rain from a density-stratified brine. The Lockport reefs were apparently covered by evaporites much as snow covers a newspaper left on the lawn. The snow falls on lawn and newspaper alike, but after several inches of snow have fallen only a vague topographic expression of the newspaper remains. If the paper is not rescued, all topography is removed by the time a thickness of snow several times the thickness of the newspaper has fallen. In the case of salt precipitation, the effect would be somewhat modified: at any one time during deposition there would be less thickness of saturated brine overlying the Lockport "hill," hence less sedimentation. Re-solution of evaporite sediment would also be more marked over the topographic high if for some reason the saturated/unsaturated brine interface moved down. Again it should be emphasized that the reef itself was not responsible for the density-layering conditions which led to the evaporite deposition, but acted only as a topographic high having local effect on salt thickness.

INDUSTRIAL USAGE OF SALINA SALTS

EARLY HISTORY OF SALINA SALT PRODUCTION

Prior to the discovery of the Salina rock salt beds, early settlers in Ohio obtained salt from shallow Pennsylvanian and Mississippian sands cropping out in the southeastern part of the state. Natural brine seeps from these outcrops were collected and evaporated to produce salt as early as 1797 (Hildreth, 1838). Later, shallow wells drilled near the seeps in many instances flowed brine to the surface. By the time of the Civil War, Ohio was a leading salt-producing state, with scores of evaporating furnaces located in a broad band between Columbiana and Meigs Counties. The yield was about 70,000 tons of salt per year (Harris and Corell, 1945). The large quantities of coal and wood fuel required in this process were abundantly available at the time.

Deep-seated rock salt beds of the Salina Group were discovered in Ontario, Canada, in 1866 (Cole, 1915, quoted in Hewitt, 1962), in Michigan in 1881 (Cook, 1914), and in New York in 1878 (Kriedler, 1963). Artificial brine production was soon established in these areas and rapidly came to dominate the market. Such brines are much more concentrated than natural brines and therefore require only about one-third as much fuel to yield the same quantity of salt. In addition they contain far fewer impurities. A comparison between natural and artificial brine chemical analysis is shown in table 1.

The production of artificial brines in surrounding states had a markedly adverse effect on the Ohio salt industry. Of this period Root (1888) writes, "The history of salt manufacture in Ohio bears the stamp of a

TABLE 1.—*Comparison between natural and artificial (Salina) brines (from Harris and Corell, 1945).*

	I	II		III
	Berea (g/l)	"Big Injun" (g/l)	Berea (g/l)	Salina (g/l)
NaCl	80.10	84.300	111.00	310.977
$CaSO_4$	0.00	0.000	0.00	4.857
$CaCl_2$	21.00	14.340	27.40	1.033
$MgCl_2$	10.39	5.590	11.60	0.462
$MgBr_2$	0.30	0.155	0.52	0.012

I—Bitterns used at Dover, Ohio, for salt manufacture, 1888.
II—Bitterns used at Pomeroy, Ohio, 1945.
III—Artificial brine made by dissolving rock salt from Salina formation.

lost cause." Salt production declined to about 30,000 tons in 1890, and most of the brine furnaces were abandoned.

Ohio's salt industry was rescued from obscurity by the fortuitous discovery of rock salt in a well drilled for natural gas by the Cleveland Rolling Mill Company. The salt discovery well at Newburg began drilling in 1886 and, curiously enough, must have been drilling at the same time that Root made his gloomy prediction concerning Ohio's salt industry. The well was completed in 1889, and the newly formed Newburg Salt Company began artificial brine production that same year from salt beds at a depth of about 2,150 feet. The graph shown in figure 8 illustrates the low level of production in the salt industry prior to this discovery and the meteoric rise thereafter as the Newburg and other brine companies began operation.

United Salt Company took over operation of the Newburg Salt Company and operated it until 1902, using the discovery well and two others located in Mill Creek valley south of Harvard Road (Cushing and others, 1931). Three other pioneer plants were built in the Cleveland area in the early 1900's. Union Salt Company established brine works at the foot of Marquette Street; however, there is no record that production was successful. A second plant of the same company, with five wells located at the foot of Madison Street, was apparently quite profitable, operating from 1890 until at least 1931 and perhaps as late as 1944 (Harris and Corell, 1945). The fourth salt plant was built at the corner of Ashland Road and Central Avenue by the Cleveland Salt Company. Production began in 1900 and lasted until at least 1931 from four known wells. The probable locations of these now abandoned brine fields are shown in figure 9.

Salt production spread from the Cleveland area to include five additional plants in northeastern Ohio.

Salt manufacture was established in Wadsworth in southeastern Medina County by the Wadsworth Salt Company in 1893. The plant had only two wells of record and survived until about 1923.

The Ohio Salt Company was formed at Rittman in Wayne County in 1898, and began salt production the

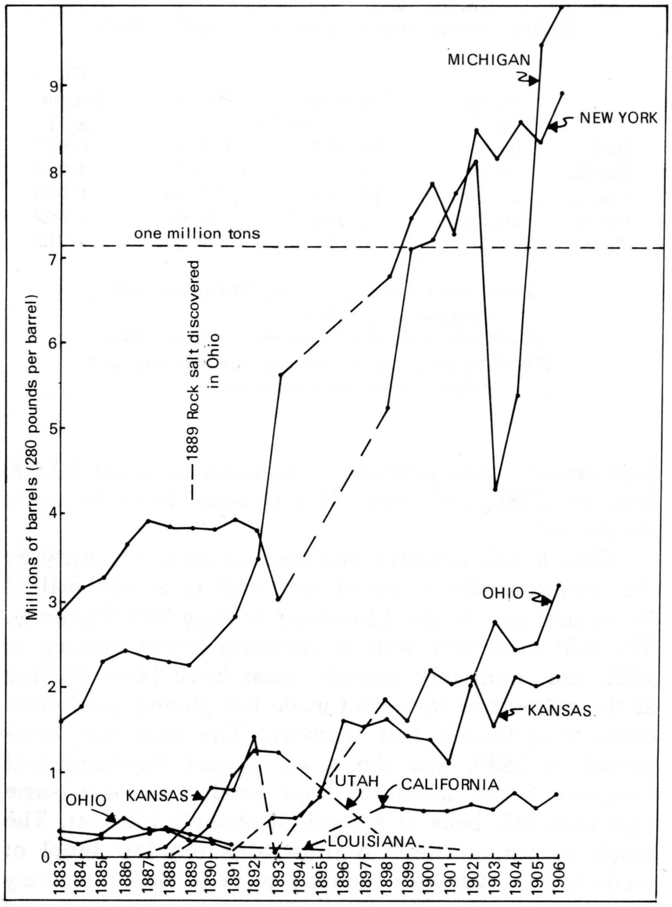

FIGURE 8.—Leading salt-producing states, 1883-1906 (from U.S. Geol. Survey, Mineral resources of the United States, and Bownocker, 1906); lines dashed where data are lacking.

same year. In 1905 there were four wells supplying brine. Morton Salt Company purchased the plant in 1948 and continues to operate it today on an expanded basis.

Colonial Salt Company was established in 1901 at Kenmore, now a suburb of Akron, in Summit County. The plant became part of the Diamond Crystal Salt Company in 1945 and still operates today.

The largest and most productive brine field in Ohio is that owned by the Diamond Shamrock Corporation, previously Diamond Alkali, near Painesville in Lake County. This plant was opened in about 1912 to supply brine for the soda ash industry. About 82 brine wells have been drilled in this area to date in seven separate brine fields.

Columbia Southern Chemical Company, now a division of PPG Industries, Inc., started production in 1899 at Barberton, southwest of Akron, in Summit County. The plant supplies large quantities of brine for both the soda ash and the chlorine industries. At least five and perhaps many more brine wells were drilled in the early 1900's, and today there are 28 wells on record, with probably many more unreported.

The early artificial brine wells were quite productive, restoring Ohio to a prominent position in the salt industry. Data from Bownocker (1906) show that individual plants could produce over 100,000 tons of salt per year in the early 1900's. Nationally, Ohio regained a position of strength in the salt industry and by 1906 was ranked third in the United States, with annual production of 450 thousand tons compared to 1.3 million tons for Michigan and 1.26 million tons for New York.

PRESENT SALT PRODUCTION IN OHIO

Scope

Salt production has increased more than tenfold since 1906. Ohio, with an annual six-million-ton yield,

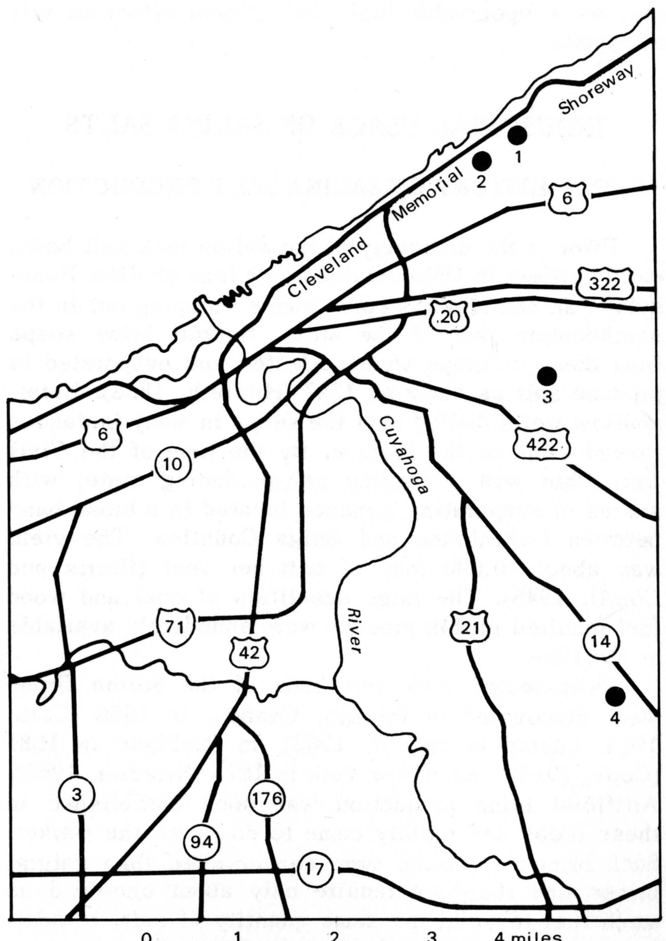

FIGURE 9.—Pioneer salt plants in the Cleveland area: (1) Union Salt Company (later United), five wells (1890-1944?); (2) Union Salt Company (1905), no history; (3) Cleveland Salt Company, four wells (1900-1931?); (4) Newberg Salt Company (later United and Union Salt Companies), three wells (1899-1902).

has become the leading salt producer in the Appalachian area and nationally trails only Texas and Louisiana (1970 data from Ohio Div. Mines and U.S. Bur. Mines). Present production in Ohio, roughly thirteen percent of the national total, is from two underground mines and four artificial brine operations. In addition, a salt plant in Meigs County utilizes natural brine from shallow Mississippian and Pennsylvanian sands. This small operation, which dates back to the Civil War, now yields less than one percent of the state's total production.

Data from the Ohio Division of Mines show that just over six million tons of salt were produced in Ohio in 1971 for an estimated value of 51 million dollars. About 830 people were employed in the industry. Figure 10 has been prepared to show the growth of the industry in recent years. Except for temporary minor declines in certain products, probably at times of labor stoppages, the overall trend for all classes of salt production is upward.

Usage of sodium chloride

Rock salt.—Rock salt is used in the production of ice cream, in hide processing, and in glass and ceramics manufacture. Purified by recrystallization, it is used in food products and for a myriad of chemical processes. The primary use of rock salt, however, is for highway ice control. The growth of state and interstate highway systems, increasing mobility of the population, and changing patterns of transportation all contribute to a growing demand for this product. As a result, the national increase in rock salt production has exceeded 12 percent per year for the past 10 years (MacMillan, 1970, p. 1212). In Ohio, in the period from 1965 to 1970, rock salt production increased about 50 percent.

The market for Ohio salt is widespread throughout the East and Midwest, and Ohio is well situated with regard to the necessary transportation facilities. The lakefront sites of both mines give ready access to all Great Lakes ports, as well as to a well-developed rail and highway network. Sales of Ohio salt have been reported from Illinois to Virginia and throughout the entire Northeast.

The impending completion of a large mine near Seneca Lake, New York, could affect Ohio's eastern markets. This mine is planned eventually to yield four

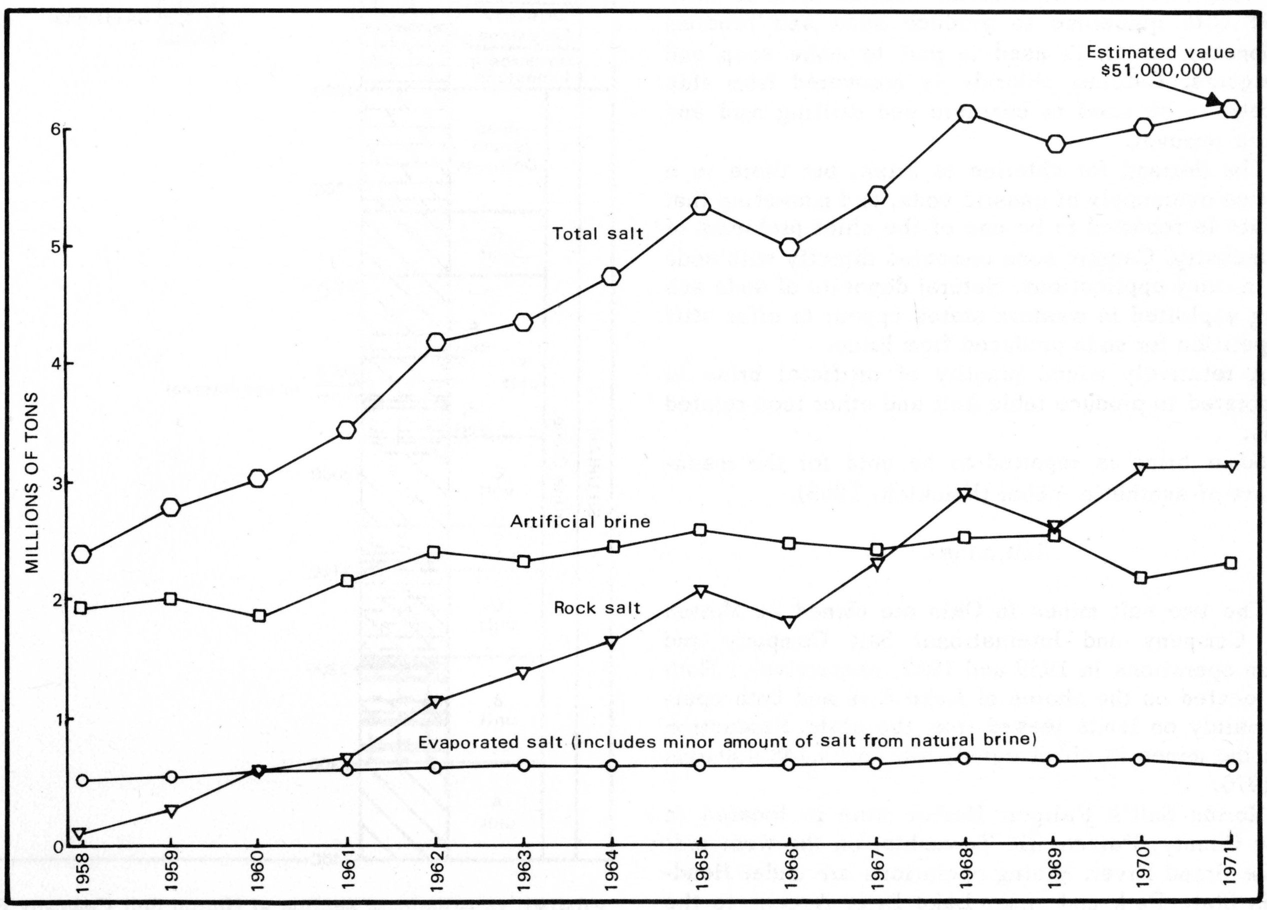

FIGURE 10.—Ohio salt production, 1958-1970 (source: Ohio Department of Industrial Relations, Division of Mines yearly reports).

million tons per year, more than twice that now produced by the two Ohio mines together. However, demand is such that the impact may be scarcely felt. Of greater impact may be an increasing opposition to the use of salt as a road-deicing agent on the grounds that surface-water pollution, vehicular corrosion, and damage to concrete may result from its use. These effects have not been fully studied, and it remains to be seen what tradeoffs society will accept in the conflict between improved winter travel made possible as a result of salting highways and the possible hazards that may accompany such use.

Artificial brine.—Artificial brine is utilized almost entirely by the chlor-alkali and associated industries. The brine, produced by solution mining, is subjected to electrolysis to yield gaseous chlorine and caustic soda (sodium hydroxide). Chlorine is in demand in a great many processes of the chemical industry, chiefly in the manufacture of plastics and resins, pulp and paper (as bleaching agents), solvents, antifreeze and antiknock compounds, and pesticides. The U.S. Bureau of Mines predicts a continuing strong demand into the year 2000, especially in the first three classes.

Caustic soda, a coproduct of chlorine, is used in the manufacture of paper, phenol, soap and bleaches, and many industrial chemicals. Caustic soda is combined with quicklime to produce soda ash (sodium carbonate), which is used in part to make soap and detergents. Calcium chloride is recovered from this process to be used in concrete and drilling mud and for ice removal.

The demand for chlorine is brisk, but there is a relative oversupply of caustic soda, and marketing that product is reported to be one of the chief problems of the industry. Caustic soda competes directly with soda ash in many applications. Natural deposits of soda ash being exploited in western states appear to offer stiff competition for soda produced from brine.

A relatively minor quantity of artificial brine is evaporated to produce table salt and other food-related items.

Some brine is reported to be sold for the manufacture of synthetic rubber (Krickich, 1965).

Salt mines

The two salt mines in Ohio are owned by Morton Salt Company and International Salt Company and began operations in 1959 and 1962, respectively. Both are located on the shores of Lake Erie and both operate mainly on lands leased from the state. Production from the mines is about equal, totaling 3,145,000 tons in 1970.

Morton Salt's Fairport Harbor mine is located in Lake County, Painesville Township, on the west side of the Grand River. Mining operations are under Headlands State Park and under Lake Erie. Access to the mine is through a 12-foot-diameter shaft which is used also for ventilation. The salt is removed from the mine through a 16-foot-diameter production shaft. Original capacity of the mine was about 300 tons per hour, but in 1967 the company began expanding capacity with the addition of improved loading and lifting equipment. Estimated capacity is now about 2½ million tons per year. Room-and-pillar mining is used, leaving about 50 percent of the salt for roof support.

The salt is taken from a 17-foot interval within the Salina F_1 salt bed; the top of the mined bed is

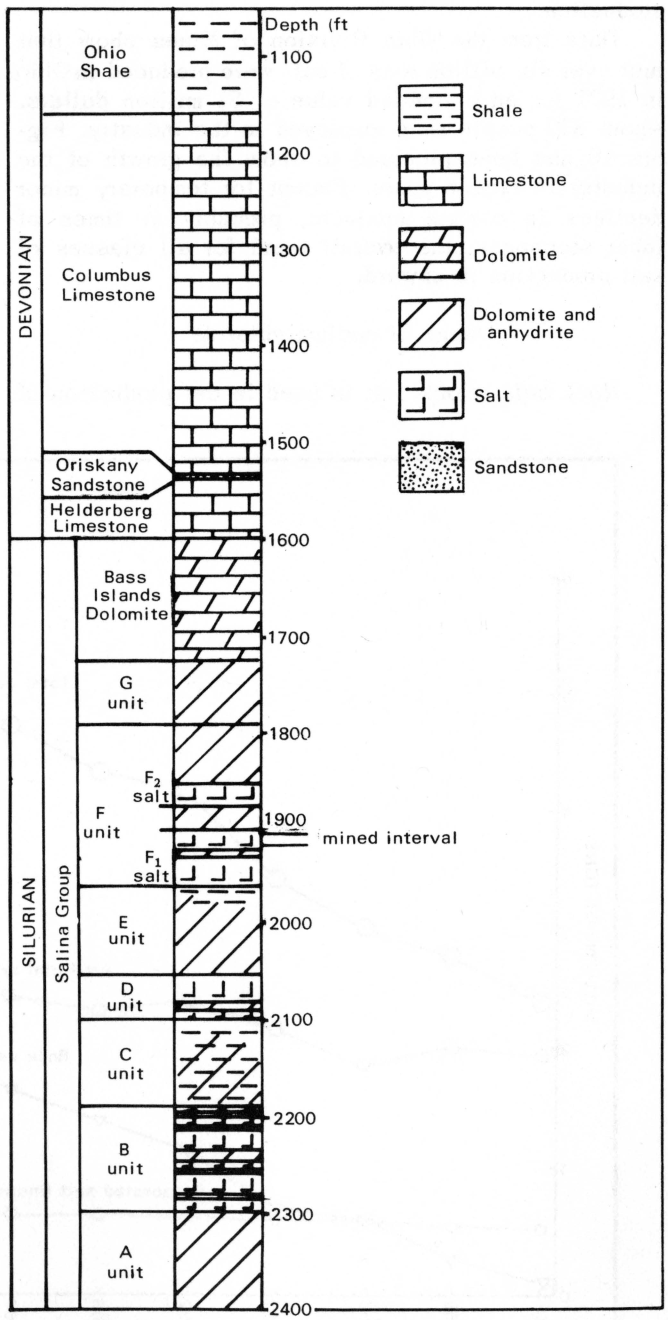

FIGURE 11.—Geologic section at Morton Salt Company Fairport Harbor mine, Lake County, Ohio.

about 1,900 feet below the surface and the base is about 1,960 feet. A 5-foot layer of anhydrite divides the F_1 salt bed into two parts, and the mine is within the upper portion of the bed. Figure 11 shows a section of the rocks penetrated in drilling the mine shafts.

International's mine is on Whiskey Island in Cleveland, Cuyahoga County. Mine workings extend to the north and west under Lake Erie. Production from this mine is from a 14- to 17-foot-thick section within the F_2 salt; the top of the F_2 salt is 1,713 feet below the surface and the base is about 1,790 feet. A schematic geologic section through the mine is shown in figure 12.

Two 16-foot-diameter shafts serve this mine. One shaft provides access for men and materials and is the ventilation input as well as the telephone, power, and signal cable route. The other shaft accommodates the production hoist, ventilation exit, and fresh-water and waste lines (Bleimeister, 1964). Production capacity is thought to be about two million tons per year, most of which goes to state and local agencies in Ohio and Pennsylvania for highway ice control. Some of the product is reported to be exported to Canada.

A problem in the current development of this mine is the reported presence of a normal fault, down-to-the-lake, with about 47 feet of displacement. The fault, paralleling the shore on the north end of the mine workings, has hindered the planned development of the mine in that direction (Jacoby, 1970). The company has recently taken additional leases from the state to the west of their present workings, and this area will be developed in the event that production is not feasible through the fault zone.

Additional salt of probable commercial quantity and quality in the F_1 unit underlies the present mine level.

Artificial brine fields

Production of brine.—Artificial brine is produced from wells drilled through deep salt beds. When drilling is complete, casing is cemented in the hole and tubing installed within the casing. Fresh water pumped into the well bore dissolves enough salt to become almost saturated. The resulting brine is pumped back to the surface where it may be sold in brine form to the chemical industry, or may be evaporated to produce a variety of salt products, including table salt.

The original brine wells were of simple construction and were operated by introducing water through casing and producing brine through tubing. These wells tended to have relatively short lives and low production rates. This well configuration tends to encourage salt solution at the top of the cavity because the fresh water, being less dense, rises to the top of the salt bed, attacking the roof of the cavity. The denser brine collects at the base of the cavity and effectively prevents solution of the lower portion of the salt bed.

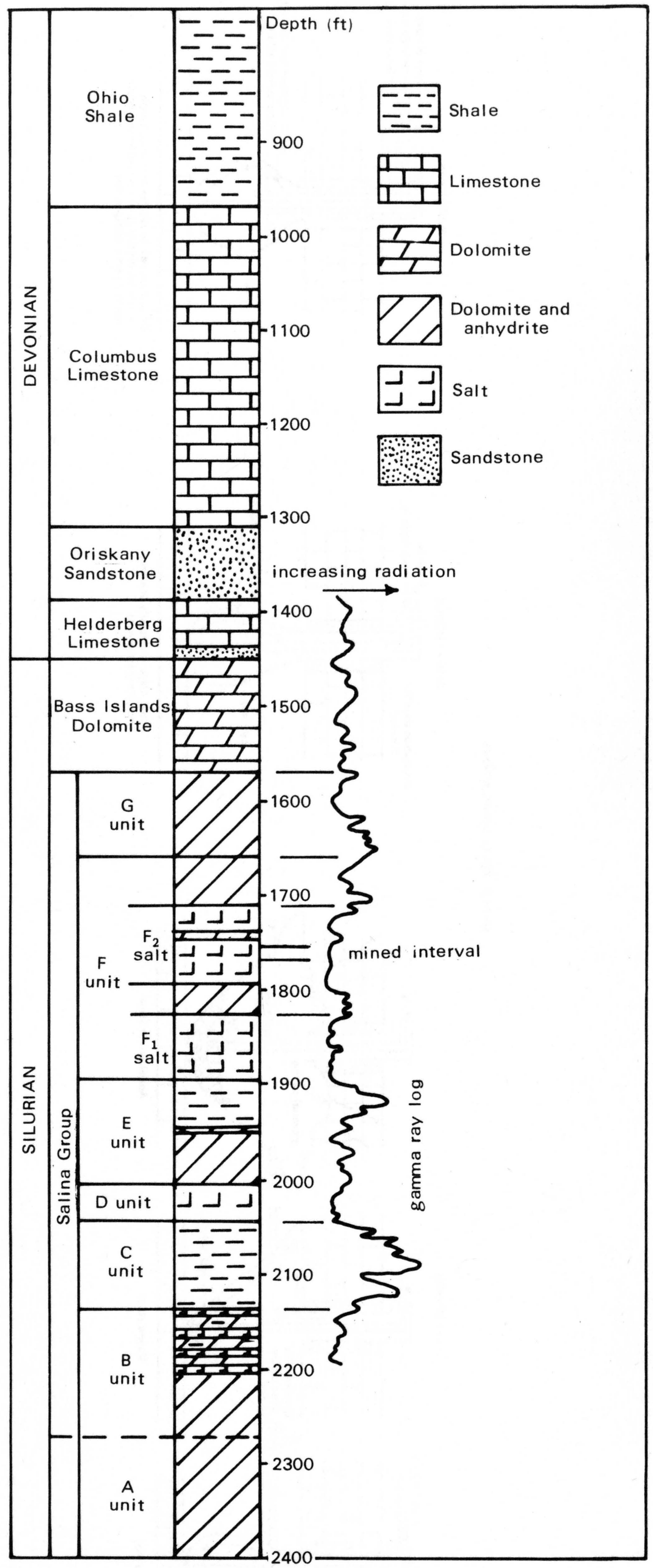

FIGURE 12.—Geologic section at International Salt Company Whiskey Island mine, Cleveland, Ohio.

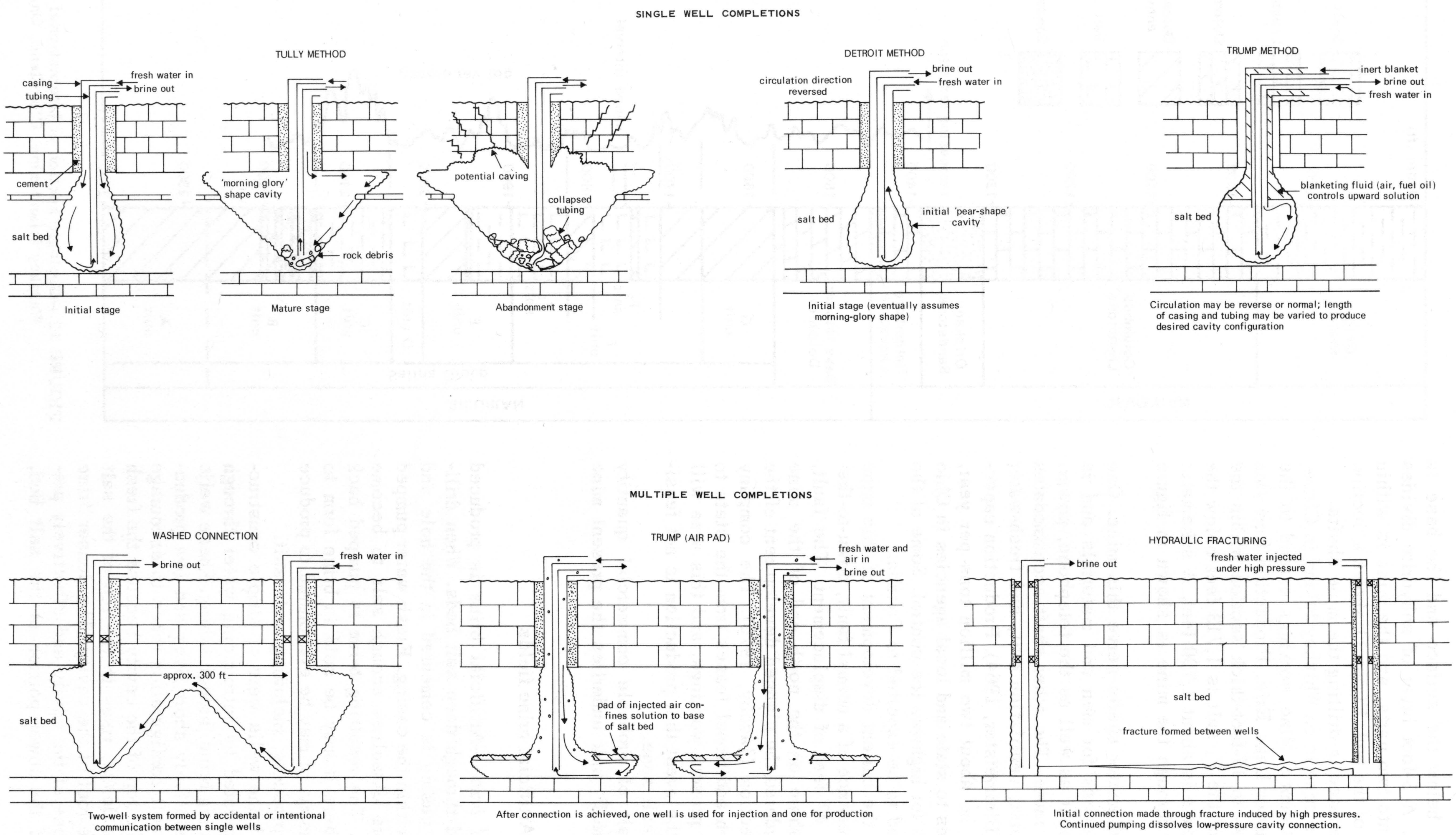

FIGURE 13.—Methods of artificial brine production (compiled from several sources).

The result is a cavity shaped like an inverted cone, or "morning glory," and having a wide lateral extent. The large diameter of solution tends to cause early roof collapse, which in many cases destroys casing and tubing. Variations of well design, chiefly the reverse circulation and Trump methods, permit more efficient salt removal by producing a more cylindrical cavity. In the reverse circulation method, water is admitted through tubing near the base of the salt bed and withdrawn from casing near the top. Tubing and casing placement may be adjusted to promote more solution near the base of the bed. The Trump method utilizes a cushion of inert fluid, such as air or fuel oil, placed at the roof of the cavity to protect it from solution. The cushion may be progressively lowered or raised during production to control the area exposed to solution.

It was noted in early brine fields that some wells would interconnect naturally after a long period of production. It was further discovered that when one of the interconnected wells was used for injection of fresh water and one for brine outlet, a long well life with high flow rates was achieved. Subsequently, attempts were made to force connections between wells by natural washing and by a modified Trump method. These attempts had some success, but it was not until the hydraulic fracturing method was introduced in the sixties that the brine operator could be assured of a reasonable chance of controlling the interconnection of wells. In this method two wells are drilled between 500 and 1,000 feet apart. Casing is cemented in one well and notched near the base of the salt bed. Fresh water is injected into this well under very high pressure to rupture the salt bed and propagate a fracture. In many cases the fracture is vertical, decreasing the chances of the fracture intersecting the target well, but, properly engineered, the fracture is horizontal (Aughenbaugh and Pullen, 1970) and does make connection. Once communication between wells is attained, fluid is pumped continuously between wells to dissolve a low-pressure tunnel, after which solution mining proceeds as through a natural connection. The paired wells can be expected to sustain a high yield for many years. Since most solution occurs between wells, there is less danger of casing and tubing damage from rock falls. It appears that most of the wells drilled in Ohio since 1965 are paired and were probably completed by fracturing, although the actual completion data are not available.

The various methods of brine well completion are depicted in figure 13.

Brine fields.—The largest brine-producing area in Ohio is owned by the Diamond Shamrock Corporation in Painesville Township, Lake County, near the town of Painesville. About 28 wells are now active on an intermittent basis.

This area is very favorably located with regard to salt beds. The typical gamma ray shown in appendix C (fig. C2) indicates that salts in the B, D, F_1, and F_2 units have an aggregate thickness of about 150 feet. The fields probably produce from all of these units.

The earliest producing area was the Main Cavity or Main Plant field, located near the lakefront east of Fairport Harbor. This field operated between 1912 and about 1946 from a total of 46 wells. Six additional Diamond Shamrock fields were later established in this area (appendix C, fig. C1, table C1), the latest being the Heisley Road field. The more recent completions seem to be from paired wells, probably fracture connected. Brine from the Diamond Shamrock fields is captive production, used in the manufacture of chlorine and soda ash.

Another major brine producer is PPG Industries, Inc., Chemical Division, with three brine fields located in Franklin and Norton Townships, Summit County, in and south of Barberton, Ohio. These locations, determined from the rather scanty records available for this field (table C2), are shown in appendix C (fig. C3). Only 28 wells are on record at the Ohio Division of Geological Survey, but, considering the duration and volume of production, it is possible that many more unreported wells were drilled. A gamma ray log from the field (appendix C, fig. C4) shows the thicknesses of the F_1 and F_2 salts exploited in this area.

As far as is known, all production is used internally. The brine undergoes electrolysis to produce chlorine and caustic soda. Quicklime produced from limestone mined on the property is mixed with the caustic soda to form soda ash, a basic raw material for the chemical industry and a major material in glass making.

Two smaller brine producers are the Morton Salt Company at Rittman, Milton Township, Wayne County, and the Diamond Crystal Salt Company at Kenmore, Coventry Township, Summit County. Locations, well records, and representative gamma ray logs for these fields are shown in appendix C (figs. C5-C8, tables C3, C4). Brine that is evaporated from these fields has a wide variety of uses: table salt, salt for food processing and preservation, water softening, pressed block for cattle feed, and chemical manufacture. Some brine is reportedly sold by the Diamond Crystal Salt Company to the nearby Firestone and Goodyear Tire and Rubber Companies for manufacture of synthetic rubber.

The Morton plant appears to produce entirely from the F_1 salt, whereas Diamond Crystal utilizes the F_1, F_2, and D salt beds.

Reserves

About 9,863 square miles of Ohio are underlain by salt, an amount calculated to be in excess of two and a half trillion tons. If one-fourth of this salt were recoverable, Ohio could, at the present rate of consumption, supply the needs of the entire nation for 32,000 years.

If an economic limit of 2,500 feet depth is arbitrarily set for salt-mining operations, a possible 1,466 square miles of northern Ohio are underlain by minable salt of which at least one bed is thicker than 25 feet. This area is shown in figure 2. All of the Ohio salts are within reach of artificial brine wells, as demonstrated by the brining operations just across the Ohio River in West Virginia, where brine is being produced from depths of as much as 6,800 feet.

The accompanying structure and isopach maps (pls. 2, 3, 4) should enable the salt prospector to choose the most favorable areas with regard to market and transportation and depth and thickness of salt for future exploratory effort. Figure 2 gives a ready picture of the depth to the top of the salt and shows areas where thick beds should be expected.

Future exploratory work should benefit greatly from the use of the many available density logs, devices which are unexcelled for delineating salt beds.

REFERENCES CITED

Alling, H. L., and Briggs, L. I., 1961, Stratigraphy of Upper Silurian Cayugan evaporites: Am. Assoc. Petroleum Geologists Bull., v. 45, no. 4, p. 515-547.

Aughenbaugh, N. B., and Pullen, M. W., 1970, Directional hydrofracturing, fact or fiction, *in* Third symposium on salt, v. 2, Cleveland 1969: Cleveland, Northern Ohio Geological Soc., p. 393-403.

American Commission on Stratigraphic Nomenclature, 1970, Code of stratigraphic nomenclature: Tulsa, Oklahoma, Am. Assoc. Petroleum Geologists, 22 p.

Bleimeister, W. C., 1964, New Cleveland mine was designed for mass recovery of salt: Eng. and Mining Jour., v. 165, no. 8, p. 86-93.

Borchert, H., and Muir, R. O., 1964, Salt deposits: New York, Van Nostrand, 338 p.

Bownocker, J. A., 1906, Salt deposits and the salt industry in Ohio: Ohio Geol. Survey Bull. 8, 42 p.

Cate, A. S., 1963, Stratigraphy of Cayugan Series in northwestern Pennsylvania, *in* Symposium on salt, Cleveland 1962; Cleveland, Northern Ohio Geological Soc., p. 19-26.

Cole, L. H., 1915, Report on the salt deposits of Canada and the salt industry: Canada Mines Br. Pub. 325, 152 p.

Cook, C. W., 1914, The brine and salt deposits of Michigan: their origin, distribution, and exploitation: Mich. Biol. and Geol. Survey Pub. 15, Geol. Ser. 12, 188 p.

Cushing, H. P., Leverett, F., and Van Horn, F. R., 1931, Geology and mineral resources of the Cleveland district, Ohio: U.S. Geol. Survey Bull. 818, 138 p.

Dellwig, L. F., and Evans, Robert, 1969, Depositional processes in Salina salt of Michigan, Ohio, and New York: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 4, p. 949-956.

Deutsch, Z. G., 1960, Brine wells and pipelines: *in* Sodium chloride, the production and properties of salt and brine, ed. by D. W. Kaufman: New York, Hafner Pub. Co., p. 142-193.

Ells, G. D., 1962, Silurian rocks in the subsurface of southern Michigan: *in* Silurian rocks of the southern Lake Michigan area, Michigan Basin Geol. Soc. Ann. Field Conf. 1962: Ann Arbor, Michigan, Edwards Bros., p. 39-49.

________1967, Michigan's Silurian oil and gas pools: Michigan Geol. Survey Rept. Inv. 2, 49 p.

Evans, C. S., 1950, Underground hunting in the Silurian of southwestern Ontario: Geol. Assoc. Canada Proc. 1950, v. 3, p. 55-85.

Fergusson, W. B., and Prather, B. A., 1968, Salt deposits in the Salina Group in Pennsylvania: Pennsylvania Geol. Survey Bull. M 58, 41 p.

Forgotson, J. M., Jr., 1957, Nature, usage, and definition of marker-defined vertically segregated units: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 9, p. 2108-2113.

Gambs, G. C., and White, G. W., 1946, Ohio's salt resources, *in* Ohio's mineral resources, pt. 3, Salt reserves: Ohio State Univ. Eng. Expt. Sta. Circ. 49, 22 p.

Griggs, R. L., 1958, The Silurian salt deposits of the northeastern United States: U.S. Geol. Survey Trace Elements Inv. Rept. 710, 29 p.

Harris, W. R., and Corell, E. J., 1945, Industrial development of salt manufacture in Ohio, pt. 2 *of* Ohio's mineral resources, pt. 3, Salt: Ohio State Univ. Eng. Expt. Sta. Circ. 47, p. 13-19.

Hewitt, D. F., 1962, Salt in Ontario: Ontario Dept. Mines Indus. Mineral Rept. 6, 38 p.

Hildreth, S. P., 1838, Salt springs, early history of the salt manufacture in Ohio: *reprinted in* Ohio's mineral resources, pt. 3, Salt: Ohio State Univ. Eng. Expt. Sta. Circ. 47, 1945, p. 1-12.

Jacoby, C. H., 1969, Correlation, faulting, and metamorphism of Michigan and Appalachian basin salt: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 1, p. 136-154.

________1970, Faults in salt mines—their impact on operations, *in* Third symposium on salt, v. 2; Cleveland 1969: Cleveland, Northern Ohio Geol. Soc. p. 447-452.

Kelley, D. R., and McGlade, W. G., 1969, Medina and Oriskany production along the shore of Lake Erie, Pierce Field, Erie County, Pennsylvania: Pennsylvania Geol. Survey Bull. M 60, 37 p.

Krickich, Joseph, 1965, The mineral industry of Ohio, *in* Minerals yearbook 1964, v. 3, Area reports, domestic: Washington, D.C., U.S. Bur. Mines, p. 767-798.

Kriedler, W. L., 1963, Silurian salt of New York State, *in* Symposium on salt, Cleveland 1962: Cleveland, Northern Ohio Geol. Soc., p. 10-18.

Krumbein, W. C., and Sloss, L. L., 1963, Stratigraphy and sedimentation: San Francisco, W. H. Freeman and Co., 660 p.

Landes, K. K., 1945, The Salina and Bass Island rocks in the Michigan Basin: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 40.

MacMillan, R. T., 1970, Sodium chloride, *in* Mineral facts and problems: U.S. Bur. Mines Bull. 650.

Matthews, R. D., 1970, The distribution of Silurian potash in the Michigan Basin: Sixth Forum on Geology of Industrial Minerals Proc., Michigan Geol. Survey Miscellany 1, p. 20-33.

Ohio Division of Mines, 1969-1970, Annual report: Columbus, Ohio Dept. Indus. Relations, Div. Mines.

Oinonen, Russel, 1965, A study of selected Salina salt beds in northeastern Ohio: Ohio Univ., M.S. thesis (unpub.), 60 p.

Pepper, J. F., 1947, Areal extent and thickness of the salt deposits of Ohio: Ohio Jour. Sci., v. 47, p. 225-239.

Raup, O. B., 1970, Brine mixing: an additional mechanism for formation of basin evaporites: Am. Assoc. Petroleum Geologists Bull., v. 54, p. 2246-2259.

Rickard, L. V., 1969, Stratigraphy of the Upper Silurian Salina Group, New York, Pennsylvania, Ohio, Ontario: New York State Mus. and Sci. Service Map and Chart Ser., no. 12, 57 p.

Root, W. J., 1888, The manufacture of salt and bromine, *in* Economic geology: Ohio Geol. Survey, v. 6, p. 653-670.

Sanford, B. V., 1965, Salina salt beds, southwestern Ontario: Canada Geol. Survey Paper 65-9, 7 p.

Schlumberger Limited, 1969, Log interpretation principles: New York, Schlumberger Ltd.

Schmalz, R. F., 1969, Deep water evaporite deposition—a genetic model: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 4, p. 798-823.

Stehli, F. G., Namy, J. N., and Aten, M. D., 1963, Evaporite facies in northeastern Ohio, *in* Symposium on salt, Cleveland 1962: Cleveland, Northern Ohio Geol. Soc., p. 31-46.

Ulteig, J. R., 1964, Upper Niagaran and Cayugan stratigraphy of northeastern Ohio and adjacent areas: Ohio Geol. Survey Rept. Inv. 51, 48 p.

U.S. Bureau Mines, 1972, Minerals yearbook 1970: Washington, D.C., U.S. Bur. Mines.

U.S. Geological Survey, 1883-1906, Mineral resources of the United States: Washington, D.C., U.S. Geol. Survey.

APPENDIX A.–SALINA CORES AND/OR CORE DESCRIPTIONS AVAILABLE AT OHIO DIVISION OF GEOLOGICAL SURVEY

County	Township	Land subdivision	Map or permit number	Core number or sample number	Operator	Lease or well name	Well number	Core interval available (depth in feet)	Core description interval (depth in feet)	Described by	Geophysical logs	Date drilled	Remarks
Ashtabula	Geneva	Sec. 2, lot 16	NA[1]	C-561	Internat. Salt	McGonigle	1	1767-2450	1767-2450	Truessel	no	6/49	Core chip samples (#706) available
	Saybrook	Lot 28	P-12	C-442	Internat. Salt	Gerald	1	1472-2400	1324-2400.5	Rector?	no	7/48	Graphic log with chemical analysis available
Cuyahoga	city	Lot 88	P-389	S-879	Sohio	Bradley	1	1483-1978	NA	NA	yes	6/60	
	Whiskey Island	city	1837 A	NA	Internat. Salt	Whiskey Island	1	NA	0-2400	Anonymous	yes	6/56	Detailed description
	Strongsville	Lot 98	275	C-598	Internat. Salt	Bore	5	NA	0-2544	Anonymous	no	4/51	Very sketchy description
Lake	Concord	Lot 18	P-19	C-774	Diamond Alkali	Fee	201	2257-2790	90-3104	Anonymous	no	11/53	Chemical analysis available; core chip samples (#731) available
	Mentor	Tr. 14, lot 1	P-22	C-663	Morton Salt	State of Ohio	1	NA	1588-2606	Bowman	no	6/54	
	Painesville	Tr. 4, lot 26	P-17	NA	Morton Salt	N. Y. C. RR.	1	NA	0-2352	Nold	no	9/53	Graphic log only
	Painesville	Tr. 4, Fowler Lots	P-14	S-565	Diamond Alkali	Fee	32	NA	1885-2349	Shearrow	yes	1/53	
	Perry	Lot 89	P-20	C-1939	Diamond Alkali	Fee	202	?	100-2475	Brown?	no	5/54	Core boxes poorly labeled
Lorain	Avon	Sec. 28	NA	C-518	Internat. Salt	Nagel	1	50-1673.5	949-1673.5	Parker	no	9/49	
	Avon	Sec. 28	P-667	NA	Internat. Salt	Farm land	1	NA	0-1969	NA	no	4/53	Sketchy well-card data
	Black River	city	P-914	LOR I	Diamond Crystal	City of Lorain	1	640-1611	640-1611	Janssens	yes	9/67	
	Sheffield	Lot 27	P-647	C-560	Internat. Salt	Hanko	1	30-1849	NA	NA	no	6/52	
Monroe	Jackson	Sec. 18	P-1594	S-1049	Sam Jack	N. Am. Coal	1	6676-6695	6564-6686	Ehlers, Tettenhorst	yes	10/62	Chemical analysis available
Portage	Aurora	Sec. 7	P-24	C-569	Internat. Salt	J. Wides	1	2447-3306	2548-3307 2587-3306.8	Winslow Duggan	no	1/51	
Summit	Coventry	Lot 10	P-366	S-865	Diamond Crystal	Fee	16	3081-3125	NA	NA	yes	3/60	
	Norton	Lot 64		955	Pittsburgh Plate Glass	Fee	3	12-2810	0-2851	Stauffer	no	12/39	
Location uncertain					Morton Salt		4	1726-2006	NA	NA	NA		May be P-36-4, tr. 4, lot 26; Lake Co., Painesville Twp.
Location uncertain					Morton Salt		9	1878-2206	NA	NA	NA		May be P-39, tr. 14, lot 2; Lake Co., Mentor Twp.
Location uncertain					Morton Salt		8	1826-1995	NA	NA	NA		May be P-38, tr. 4, lot 25; Lake Co., Painesville Twp.

[1]Not available

APPENDIX B.–SUMMARY OF CONTROL WELL DATA

ABBREVIATIONS

C	*Caliper log*	ML	*Microlog*
D(Piper)	*Density log by operator other than Schlumberger*	NP	*Not present*
DF	*Derrick floor*	p	*Partial log; entire Salina not logged*
FDC	*Density log (compensated) by Schlumberger*	RT	*Rotary table*
FDL	*Density log (uncompensated) by Schlumberger*	S	*Sonic log*
GR-N	*Gamma ray-neutron log*	T	*Topographic*
KB	*Kelly bushing*	*	*Data derived by comparison of gamma ray log with those of nearby wells*
LL	*Laterolog*		

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft)		F salt thickness (ft)				Depth (ft)	E salt thickness (ft)	D salt thickness (ft)	Depth (ft)		B salt thickness (ft)	Depth (ft)	Total salt thickness (ft)	Type data
						Top of G unit	Top of F unit	F_1	F_2	F_3	F_4	Top of E unit			Top of C unit	Top of B unit		Top of A unit		
ASHLAND COUNTY																				
Jackson	Sec. 6	Hoagland	Stentz	2448	1251 KB	1987	2080	0	0	0	0	2164	0		2254	2318	0	2400	0	GR-N
Jackson	Sec. 21	Rumbaugh	Rumbaugh	1332	1180 T	2019	2019	0	0	0	0	2201	0		2300	2364	0	2450	0	GR-N
Orange	Sec. 35	Sunshine	Jones	2574	1154 KB	1853	1952	0	0	0	0	2033	0		2130	2200	0	2285	0	GR-N
Perry	Sec. 11	M & G Oil	Cehrs	2387	995 T	1917	2028	0	0	0	0	2113	0		2206	2274	0	2354	0	GR-N
ASHTABULA COUNTY																				
Andover	Sec. 3	McConnell	French	206	1063 KB	2771	2875	30	0	0	0	3035	0	30	3240	3337	45*	3473	105*	GR-N
Austinburg	Lot 17	Mansfield	Cerbin	234	834 KB	2098	2204	40	0	0	0	2317	?	20	2410	2487	62*	2633	122+	D(Shelwell)
Austinburg	Lot 48	Northern Natural	Judson	91	851 DF	2119	2213	46*	0	0	0	2350	2*	35	2495	2570	62*	2711	145*	GR-N
Conneaut	Lot 28	Grantly	Elonen	90	850 DF	2178	2279	0	0	0	0	2342	0	0	2445	2491	0	2569	0	GR-N
Conneaut	Lot 32	Shearer	Schor	189	818 KB	2119	2213	0	0	0	0	2280	0	0	2390	2450	45	2570	45	FDL
Conneaut	Lot 47	Tidal	Wallace	167	693 KB	1903	1992	0	0	0	0	2052	0	0	2157	2213	29	2326	29	GR-LL, S
Denmark	Sec. 17, lot 2	Belden & Blake	Fowlie	54	942 KB	2322	2422	35*	0	0	0	2549	4*	24	2684	2760	53*	2891	116*	GR-N
Denmark	Sec. 7, lot 2	Mansfield	Teets	219	936 KB	2294	2391	34	0	0	0	2507	2	27	2637	2717	57	2850	120	D(Shelwell)
Denmark	Sec. 8, lot 4	Continental	Westfall	377	958 KB	2327	2426	62	0	0	0	2575	5	30	2726	2794	63	2933	160	FDC
Dorset	Lot 4	Benedum	Lindholm	138	1089 KB	2609	2712	?	0	0	0	2854	?	20	2995	3080	50*	3225	70+	GR-N
Geneva	Sec. 2, lot 16	Internat. Salt	McGonigle	--	689 GR	1872	1963	42	0	0	0	2087	0	41	2210	2293	78	2426	161	Core
Harpersfield	Lot 35	Horizon	Burkholder	196	857 KB	2140	2240	36	0	0	0	2345	0	27	2463	2536	78	2676	141	FDL
Hartsgrove	Lot 20	Mansfield	Bluhm	361	807 KB	2168	2271	70	24	0	0	2454	3	35	2611	2682	68	2830	200	FDC
Hartsgrove	Lot 31	Northern Natural	Musial	99	976 KB	2376	2482	60*	29*	0	0	2667	4*	32	2817	2898	73*	3043	198*	GR-N
Hartsgrove	Lot 67	Smith	Roach	82	1085 KB	2446	2549	55	29	0	0	2732	4	30	2882	2960	70	3103	188	GR-N, LL, S
Jefferson	Lot 8, Old Survey	Simpson	Moody	216	852 KB	2108	2206	58	0	0	0	2347	3	28	2486	2557	63	2698	152	FDC
Jefferson	Lot 121	Mansfield	Hubbard	259	994 KB	2293	2392	61	0	0	0	2538	2	30	2681	2760	63	2901	156	D(Shelwell)
Jefferson	Lot 134	Quaker State	Kemmer	213	914 KB	2206	2310	54	0	0	0	2450	3	27	2596	2674	77	2812	161	FDC
Kingsville	Lot 6	Belden & Blake	Whiting	57	855 DF	2196	2236	0	0	0	0	2308	0	0	2406	2470	50	2606	50	GR-LL, ML-C, S
Kingsville	Lot 32	Atlas	Infirmary	27	782 T	2017	2109	0	0	0	0	2167	?	?	2285	2346	10*	2465	10+	GR-LL-N
Lenox	Lot 13	Mansfield	Hamilton	222	1011 KB	2349	2452	65	0	0	0	2601	3	35	2752	2822	59	2975	162	D(Shelwell)
Lenox	Lot 24	Mansfield	Springer	218	977 KB	2278	2380	54	0	0	0	2534	3	30	2686	2757	58	2903	145	D(Shelwell)
Lenox	Lot 40	Mansfield	Dietrich	231	907 KB	2204	2305	65	0	0	0	2456	1	32	2609	2680	54	2829	152	D(Shelwell)
Monroe	Lot 1S	McConnell	Brydle	73	860 KB	2173	2267	0	0	0	0	2330	0	5	2442	2505	52*	2645	57	GR-LL-N, S
Monroe	Lot 12N	Britton	Mononen	174	938 DF	2284	2375	0	0	0	0	2442	0	0	2551	2613	39*	2742	39	GR-S
Monroe	Lot 22S	Union Carbide	Tuttle	185	934 KB	2344	2434	0	0	0	0	2496	?	?	2620	2685	46	2818	46+	GR-LL-N, pFDL
Monroe	Lot 23S	Union Carbide	Braden	211	913 KB	2267	2363	0	0	0	0	2428	0	32	2573	2634	59	2773	91	FDC
Morgan	Lot 19	U. S. Gas	Roulston	286	871 KB	2129	2230	58	0	0	0	2382	2	34	2536	2606	68	2742	162	D(Shelwell)
Morgan	Lot 40	Mouser	Jamison	88	882 T	2147	2246	?	0	0	0	2400	6*	25	2545	2624	?	2774	31+*	GR-N
Morgan	Lot 113	Belco	Heidecker	375	803 KB	2156	2258	69	4	0	0	2419	1	32	2570	2638	77	2796	183	FDC
Morgan	Lot 128	Mansfield	Gliniak	243	861 KB	2181	2287	69	0	0	0	2448	2	35	2602	2673	62	2825	168	D(Shelwell)
New Lyme	Lot 10	Mansfield	Fimiani	278	956 KB	2345	2451	64	12	0	0	2625	1?	31	2778	2863	60	3019	168?	D(Shelwell)
New Lyme	Lot 17	McConnell	Kaderly	214	1054 KB	2569	2677	65*	14*	0	0	2858	?	?	3026	3098	?	3232	79+*	GR
New Lyme	Lot 25	Texaco	Fetters	371	1042 KB	2513	2616	67	11	0	0	2790	4	31	2951	3024	65	3165	178	FDC
Orwell	Lot 2	Northern Natural	Hasznos	131	862 KB	2390	2498	66	14	0	0	2681	4	30	2832	2914	48	3051	162	GR-N, LL, S

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft) Top of G unit	Depth (ft) Top of F unit	F salt thickness (ft) F_1	F_2	F_3	F_4	Depth (ft) Top of E unit	E salt thickness (ft)	D salt thickness (ft)	Depth (ft) Top of C unit	Depth (ft) Top of B unit	B salt thickness (ft)	Depth (ft) Top of A unit	Total salt thickness (ft)	Type data
ASHTABULA COUNTY (continued)																				
Pierpont	Lot 15	Felmont	Brayman	193	977 KB	2360	2456	35*	0	0	0	2590	0*	15*	2745	2820	49*	2958	99*	GR-N
Pierpont	Lot 60	East Ohio	Matulis	102	1088 DF	2548	2646	15*	0	0	0	2760	0*	20*	2898	2978	50*	3122	85*	GR-N
Plymouth	Lot 79	Buckeye Mgmt.	Wood	461	861 KB	2102	2194	30*	0	0	0	2313	0?	24*	2430	2489	61*	2625	115*	GR-N
Richmond	Lot 16	Northern Natural	Romanowski	98	1067 DF	2597	2688	20*	0	0	0	2813	0*	25*	2966	3053	49*	3194	94*	GR-N
Rome	Lot 25	Wehmeyer	Kellogg	86	875 KB	2268	2373	63*	22*	0	0	2553	8*	32*	2703	2788	74*	2932	199*	GR-LL
Saybrook	Lot 6S	Diamond Alkali	Wild	21	636 DF	1790	1878	0	0	0	0	1951	0*	18*	2062	2144	82*	2284	100*	GR-N
Saybrook	Lot 27	Simpson	Collins	212	682 DF	1781	1876	0	0	0	0	1943	0*	32*	2075	2145	67*	2286	99*	GR-N
Saybrook	Lot 28	Internat. Salt	Gerald	12	691 GR	1856	?	0	0	0	0	?	0	18	2170	2240	80	2381	98	Core
Sheffield	Sec. 3, lot 14	Belden & Blake	Gilbert	64	877 KB	2190	2274	0	0	0	0	2340	0	6	2459	2531	65	2671	71	FDL
Trumbull	Lot 30, div. N	Horizon	Rhoa	191	984 KB	2301	2402	57	18	0	0	2572	3	29	2713	2790	72	2945	179	FDL
Windsor	Lot 1, R. 10	Northern Natural	Ritchie	137	1073 KB	2658	2762	85	18	0	0	2964	10	32	3127	3211	53	3337	198	GR-N, pLL-S
BELMONT COUNTY																				
Union	Sec. 4	Texaco	Gillespie	129	1233 DF	5715?	--	0	?	?	60*	?	50+	?	--	--	?	6593?	60+*	Sample desc.
CARROLL COUNTY																				
Brown	Sec. 2W	Texaco	Burns	426	1137 KB	3795	3949	58	21	1	0	4185	62		4401	4499	0	4581	142	FDC
Brown	Sec. 4	Westrans	Foster	479	1248 KB	3970	4130	60	29	7	0	4386	64		4600	4700	0	4786	160	FDC
Brown	Sec. 24W	Belden & Blake	Whitacre	288	1062 KB	3815	3973	52	20	5	0	4214	46		4413	4517	0	4598	123	FDL
Brown	Sec. 24E	Humble	Davies	212	1257 KB	4148	4316	64	20	12	0	4572	59		4802	4985	0	4985	155	GR-LL-N, S-C
Brown	Sec. 36	Stocker & Sitler	Clark	286	1182 KB	4173	4336	49	20	7	0	4587	54		4801	4906	0	4989	130	FDL
East	Sec. 28	Mansfield	Felton	515	1172 KB	4494	4642	56	23	13	42	4951	84		5196	5304	0	5392	218	D(Shelwell)
Harrison	Sec. 5	Pan American	Duvall	313	1082 KB	4190	4343	49*	18*	10*	0	4596	45*	15*	4832	4912	0	4994	137*	GR
Monroe	Sec. 3	All States	Cross	357	1049 DF	4070	4240	36	17	10	0	4483	33		4681	4764	0	4844	96	FDC
Monroe	Sec. 5	Mustang	Raeder	332	1109 KB	4061	4223	47	13	8	5	4483	41		4681	4776	0	4857	114	FDC
Orange	Sec. 12	Stocker & Sitler	Miller	573	1032 KB	4115	4277	21	8	8	0	4529	37	15	4740	4824	0	4905	89	FDC
Rose	Sec. 3	Stocker & Sitler	Little	351	1024 KB	3879	4035	50*	?	6*	0	4276	62*		4520	4615	0	4696	118+*	GR
Rose	Sec. 8	Stocker & Sitler	Sandefur	471	1100 KB	3947	4110	50*	18*	15*	0	4362	46*		4580	4666	0	4747	129*	D(Piper)
Rose	Sec. 13	Stocker & Sitler	Dierick	477	970 KB	3796	3954	45*	8*	8*	0	4198	48*		4416	4500	0	4580	109*	D(Piper)
Rose	Sec. 16	Stocker & Sitler	Grosenbaugh	438	1052 KB	3884	4035	58	24*	6*	0	4284	45*		4498	4589	0	4669	133*	D(Piper)
Rose	Sec. 17	Stocker & Sitler	Sommer	277	1130 KB	3886	4030	?	?	?	0	4263	?		4490	4581	0	4662	?	D(Birdwell)
Rose	Sec. 23	Belden & Blake	Whitacre	422	1040 KB	3760	3916	53	28	0	0	4155	44		4369	4457	0	4537	125	FDC
Rose	Sec. 24	Belden & Blake	Hahn	425	1025 KB	3719	3881	48	27	0	0	4112	42		4321	4410	0	4490	117	FDC
Rose	Sec. 26	Cotten	Franklin	317	1117 KB	3851	4009	48	9	6	0	4246	52		4469	4555	0	4634	115	D(Piper)
Rose	Sec. 34	Belden & Blake	James	290	1060 KB	3639	3796	46	20	0	0	4016	35		4220	4309	0	4388	101	FDC
Rose	Sec. 36	Stocker & Sitler	Nofsinger	234	952 KB	3561	3718	59	32	0	0	3954	40		4152	4248	0	4328	131	FDL
Union	Sec. 35	Duchscherer	Grove	330	1241 KB	4504	4660	30	23	14	58	4964	75		5187	5279	0	5362	200	FDC
Washington	Sec. 4	Mgmt. Control	McAllister	553	1126 KB	4513	4670	47	24	12	20	4948	56	27	5193	5285	0	5370	186	FDC
COLUMBIANA COUNTY																				
Butler	Sec. 31	Tri-State	Sanor	620	1310 KB	4186	4334	67*	25*	18*	45	4651	69*		4878	4982	0	5069	224*	GR-N
Center	Sec. 7	Tri-State	Sell	607	1300 KB	4458	4616	48	16	15	50	4930	66		5158	5263	0	5350	195	FDC
Center	Sec. 29	Belco	Darcy	618	1139 KB	4357	4517	57	19	13	56	4846	77		5095	5202	0	5290	222	FDC
Hanover	Sec. 10	Atlas	Batzli	539	1221 KB	4253	4415	53	17	13	20	4718	50		4964	5066	0	5154	153	GR-LL-N, S-C
Hanover	Sec. 22	Quaker State	Gruber	593	1262 KB	4395	4556	41	20	14	38	4868	70		5113	5220	0	5308	183	FDC
Hanover	Sec. 34	East Ohio	Burrows	559	1170 KB	4316	4476	43	32	16	58	4797	81		5043	5146	0	5233	230	FDL
Knox	Sec. 5	Prof. Petroleum	Brunner	562	1082 KB	3662	3814	74	34	16	4	4101	56		4320	4420	0	4502	184	FDL
Knox	Sec. 7	Tri-State	Alliance	638	1149 KB	3750	3893	77	32	17	22	4195	56		4408	4513	0	4597	204	FDC
Knox	Sec. 12	East Ohio	Denny	592	1163 KB	3832	3984	106	33	19	24	4340	67		4575	4684	0	4768	249	FDL
Knox	Sec. 20	Tri-State	Bandy #4	624	1234 KB	3883	4032	?	?	11	19	?	?		?	?	?	?	30+	FD
Knox	Sec. 20	Tri-State	Bandy #1	614	1209 KB	?	?	?	?	?	?	?	?		?	?	?	4693	?	FD
Madison	Sec. 15	Galey	Gilson	626	1135 KB	4797	4955	52	18	18	92	5324	67		5600	5705	0	5795	247	FDC
Salem	Sec. 36	Mfg. Light	Halverstadt	328	1250 DF	4462	4625	45*	18*	18*	52*	4945	69*		5182	5290	0	5379	202*	GR
West	Sec. 34	Mgmt. Control	Cowden	662	1252 KB	4294	4449	68	30	16*	0?	4727	38	26*	4952	5050	0	5137	178*	GR, D(Birdwell)

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft)		F salt thickness (ft)				Depth (ft)	E salt thickness (ft)	D salt thickness (ft)	Depth (ft)		B salt thickness (ft)	Depth (ft)	Total salt thickness (ft)	Type data
						Top of G unit	Top of F unit	F_1	F_2	F_3	F_4	Top of E unit			Top of C unit	Top of B unit		Top of A unit		
COSHOCTON COUNTY																				
Clark	Lot 1 (2Q)	Midwest	Reed	1727	798 DF	2388	2500	0	0	0	0	2615	0	0	2722	2776	0	2846	0	GR-N
Crawford	Sec. 4	Kin-Ark	Cox	1825	1201 KB	3168	3299	0	0	0	0	3432	7	0	3576	3642	0	3712	7	FDL
Crawford	Sec. 16	Phillips	Brenley	1995	936 KB	2874	3011	0	0	0	0	3142	5	0	3277	3338	0	3405	5	FDC
Franklin	2Q	Quaker State	BSA	2020	860 DF	2870	2987	0	0	0	0	3130	0	0	3253	3310	0	3373	0	FDC
Jackson	Sec. 7	Arrowhead	Foster	1269	856 DF	2522	2630	0	0	0	0	2754	0	0	2840	2911	0	2992	0	GR-N
Keene	Lot 11 (2Q)	Sanders	Lowery	1225	800 T	2594	2709	0	0	0	0	2827	0	0	2942	3003	0	3070	0	GR-N
Keene	Lot 15 (4Q)	Roberson	Geib	880	809 DF	2790	2900	0	0	0	0	3027	?	?	3150	3213	0	3287	?	GR-N
Mill Creek	Sec. 4	Oxford	Bechtol	1390	990 T	2725	2841	0	0	0	0	2954	0	0	3069	3130	0	3196	0	GR-N
Mill Creek	Sec. 10	Natl. Assoc.	Lower	1257	865 KB	2747	2877	0	0	0	0	3007	0	0	3136	3197	0	3267	0	GR-N
CUYAHOGA COUNTY																				
city	Cleveland	Internat. Salt	#1 Whiskey Island	1837A	585 DF	1574	1668	64	68	0	0	1896	7	31	2046	2138	43	2272?	213	Core desc.
Strongsville	Lot 98, sec. 8	Internat. Salt	#5 Bore	275	910 GR?	1853	--	58	25*	0	0	2137	0*	28*	2273	2368	25*	2484?	136*	Sketchy core desc.
ERIE COUNTY																				
Florence	Lot 18	Neuberger	Alaimo	26	830 DF	939	1026	0	0	0	0	1099	0	0	1190	1269	0	1361	0	GR-N
Florence	Lot 43	Kubat	Hunter	31	800 KB	939	1019	0	0	0	0	1090	0	0	1182	1260	0	1348	0	FDC
Florence	Lot 68	Murphy	Hanko	24	738 DF	915	1007	0	0	0	0	1080	0	0	1183	1270	0	1350	0	GR-N
Vermilion	Sec. 2	E & W	Hauf-Miller	34	720 DF	873	962	0	0	0	0	1035	0	0	1120	1193	0	1285	0	GR-N
Vermilion	Lot 6, sec. 3	E & W	Peck	28	629 DF	774	863	0	0	0	0	932	0	0	1030	1107	0	1189	0	GR-N
Vermilion	Lot 9, tr. 1	Murphy	Kukes	21	764 KB	946	1045	0	0	0	0	1118	0	0	1210	1295	0	1376	0	GR-N, pFDL
GEAUGA COUNTY																				
Auburn	Lot 2, sec. 3, tr. 1	Quaker State	Timmons	26	1226 KB	2714	2827	80	54	0	0	3048	17	39	3225	3304	43	3435	233	FDC
Burton	Lot 2	Best	Pomeroy	13	1177 KB?	?	?	72	44	0	0	?	?	38	?	?	?	?	38+	Oinonen thesis (1965)
Middlefield	Lot 12	Westrans	Harper	31	1137 KB	2668	2777	85	12	0	0	2970	13	40	3138	3220	36	3339	186	GR-D(Birdwell)
Middlefield	Lot 50	Westrans	Miller	28	1266 KB	2851	3091	100	45	0	0	3204	7	35	3358	3440	32	3551	219	GR-D(Birdwell)
Newbury	Lot 38, tr. 3	Quaker State	Oravec	27	1223 KB	2700	2814	77	45	0	0	3023	4	29	3173	3253	20	3349	175	FDC
Thompson	Sec. 25	Mansfield	Turner	21	1154 KB	2495	2595	70	21	0	0	2773	7	26	2928	3003	69	3151	193	FDC
GUERNSEY COUNTY																				
Adams	Sec. 7	Cushing & Bradshaw	Wyers	1082	1070 KB	3620	3759	0	0	0	0	3931	6	0	4085	4149	0	4216	6	D(Shelwell)
Adams	Sec. 10	Marks	Dix	1148	1038 KB	3685	3832	0	0	0	0	4010	13	0	4163	4228	0	4296	13	D(Shelwell)
Adams	Sec. 15	Lakeshore	Marshall	782	1007 KB	3513	3649	0	0	0	0	3820	0	0	3956	4015	0	4078	0	GR-LL-N, S-C
Cambridge	Sec. 9	Camden	Mercer	1259	978 KB	3879	4033	0	0	0	0	4221	23	0	4381	4453	0	4522	23	D(Basin)
Jackson	Sec. 13	Western	Shriver	1085	903 KB	3821	3972	0	0	0	0	4164	9*	0	4317	4386	0	4450	9*	D(Piper)
Jackson	Sec. 17	Western	Toth	1050	1021 KB	3926	4080	0	0	0	0	4266	?	0	4421	4489	0	4554	?	GR-N
Knox	Sec. 9	Natl. Treasure	Miller	1221	958 KB	3540	3680	0	0	0	0	3854	19	0	4022	4086	0	4150	19	FDC
Liberty	Sec. 18	Guernsey	State Hospital	1228	811 KB	3609	3760	0	0	0	0	3948	24*	0	4110	4178	0	4240	24*	GR-D(Sand Surveys)
Madison	Sec. 8	Westland	Bennett	917	1040 KB	4329	4496	0	0	0	0	4703	30	0	4897	4983	0	5060	30	FDC
Monroe	Sec. 23	An-Car	Waggoner	1472	1052 KB	4033	4191	0	0	0	0	4382	32	10	4573	4641	0	4711	42	GR-D(Shelwell)
Richland	Sec. 9W	Southern Triangle	Harbaugh	1061	1020 KB	4307	4467	0	0	0	0	4675	22	0	4845	4922	0	4986	22	FD(Shelwell)
Richland	Sec. 10	Southern Triangle	Potts	971	830 KB	4205	4371	0	0	0	0	4580	16	0	4755	4837	0	4901	16	FDC
Richland	undiv.	Southern Triangle	Gattrell	1127	1074 KB	4561	4728	0	0	0	0	4941	20	0	5113	5199	0	5263	20	D(Shelwell)
Richland	Sec. 18E	Southern Triangle	Craig	1042	1034 KB	4576	4740	0	0	0	0	4960	30	0	5152	5233	0	5298	30	D(Shelwell)
Richland	Lot 18	Southern Triangle	Watershed #4	1125	875 KB	4339	4505	0	0	0	0	4720	30	0	4900	4979	0	5042	30	D(Shelwell)
Richland	Sec. 20	Southern Triangle	Smith	979	912 KB	4276	4443	0	0	0	0	4655	21	0	4836	4914	0	4978	21	FDC
Richland	Sec. 22	Southern Triangle	Kirtley	1012	975 KB	4260	4420	0	0	0	0	4628	15	0	4800	4879	0	4942	15	D(Shelwell)
Spencer	Sec. 3	Pointer	Kastelic	978	1023 KB	3932	4077	0	0	0	0	4258	2*	0	4400	4470	0	4532	2*	GR-N
Spencer	Sec. 5	Duchscherer	Keith	839	1006 KB	3791	3950	0	0	0	0	4133	0	0	4248	4307	0	4368	0	D(Sand Surveys)
Spencer	Sec. 18	Liberty	Bowen	922	1015 DF	3844	3976	0	0	0	0	4152	0	0	4282	4352	0	4410	0	GR-N
Spencer	Sec. 22	Stocker & Sitler	Moorhead	1202	860 KB	3819	3962	0	0	0	0	4145	0	0	4280	4352	0	4410	0	GR-N
Spencer	Sec. 23	Liberty	Secrest	918	833 KB	3830	3987	0	0	0	0	4209	5	0	4351	4416	0	4473	5	D(Allegheny)
Spencer	Sec. 36	Liberty	Cupyk	931	968 KB	4094	4251	0	0	0	0	4470	0	0	4637	4700	0	4756	0	GR-N
Valley	Sec. 2W	Cole	Brosius	949	1008 KB	4000	4154	0	0	0	0	4354	9*	0	4507	4576	0	4637	9*	D(Sand Surveys)
Valley	Sec. 4	Southern	Sherby	950	809 KB	3934	4091	0	0	0	0	4297	18	0	4457	4538	0	4601	18	FDC
Valley	Sec. 6	Tip Top	Troyan	919	928 KB	3934	4089	0	0	0	0	4289	6	0	4436	4508	0	4569	6	FDC
Valley	Sec. 11W	Summit	Cubbinson	947	970 KB	3959	4118	0	0	0	0	4313	0	0	4453	4519	0	4578	0	D(Sand Surveys)

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft) Top of G unit	Depth (ft) Top of F unit	F salt thickness (ft) F_1	F_2	F_3	F_4	Depth (ft) Top of E unit	E salt thickness (ft)	D salt thickness (ft)	Depth (ft) Top of C unit	Depth (ft) Top of B unit	B salt thickness (ft)	Depth (ft) Top of A unit	Total salt thickness (ft)	Type data
GUERNSEY COUNTY (continued)																				
Valley	Sec. 11W	Duchscherer	Wilson	923	818 KB	3835	3992	0	0	0	0	4190	21*	0	4354	4423	0	4482	21*	D(Sand Surveys)
Valley	Sec. 14W	Cole	Sekel	886	827 KB	3837	3987	0	0	0	0	4187	18	0	4351	4421	0	4479	18	D(Sand Surveys)
Westland	2Q	MB	Mallett	977	981 KB	3573	3703	0	0	0	0	3873	0	0	4003	4071	0	4140	0	FDC
Westland	3Q	Ridge Oil	Stade	851	989 KB	3676	3818	0	0	0	0	3998	0	0	4128	4196	0	4256	0	FDC
Westland	Sec. 9	National	Scott	1160	934 KB	3661	3805	0	0	0	0	3985	12	0	4138	4206	0	4269	12	FDC
Westland	Sec. 13	National	Blackstone	1161	905 KB	3622	3770	0	0	0	0	3950	7	0	4100	4170	0	4232	7	FDC
Westland	Sec. 19	Black River	Hayes	845	994 DF	3750	3906	0	0	0	0	4090	6	0	4242	4310	0	4374	6	FDC
Westland	3Q	Duchscherer	Ohio Power	905	1101 KB	3802	3932	0	0	0	0	4105	0	0	4231	4300	0	4360	0	D(Sand Surveys)
Westland	Sec. 21	Duchscherer	Manning	869	870 KB	3709	3860	0	0	0	0	4053	11*	0	4197	4266	0	4327	11*	D(Sand Surveys)
Wheeling	Sec. 19	Black River	Fieldson	844	1074 KB	3872	4021	0	0	0	0	4203	31	0	4385	4452	0	4520	31	FDC
Wills	undiv.	Westrans	Cunningham	1074	934 KB	4307	4471	0	0	0	0	4678	19	0	4856	4940	0	5002	19	FDC
Wills	Sec. 3S	Westrans	Henderson	984	887 KB	4392	4555	0	0	0	0	4770	20	0	4945	5029	0	5094	20	FDC
HARRISON COUNTY																				
Franklin	Sec. 10	East Ohio	Shuss	95	1087 KB	4336	4499	12	7	4	15	4742	40		4938	5023	0	5103	78	GR-LL-N, S-C
Freeport	Sec. 24	Amerada	Bardall	104	1127 KB	4487	4656	4	9	0	5	4884	46		5088	5176	0	5257	64	FDC
Green	Sec. 28S	McCormick	Birney	103	1127 KB	5152	5334	3	14	11	60	5633	99		5896	5986	0	6069	187	FDC
North	Sec. 7	Pan American	Luneman	101	1089 KB	4509	4661	17	14	6	66	4971	50		5199	5284	0	5365	153	FDC
Washington	Sec. 32	Atlas	Gunning	93	1221 KB	4433	4597	7	3	0	0	4814	25		4999	5086	0	5166	35	GR-LL-N, S-C
HOLMES COUNTY																				
Berlin	Lot 10 (4Q), T. 9, R. 6	Arrowhead	Hochstetler	1115	1181 DF	2897	3019	0	0	0	0	3127	7*		3273	3337	0	3410	7*	GR-N
Berlin	Lot 12 (3Q), T. 9, R. 5	Amerada	Geib	1279	1088 KB	2982	3111	0	0	0	0	3233	19		3397	3467	0	3536	19	GR-C
Clark	Sec. 18	Kin-Ark	Erb	1297	1123 KB	3128	3259	0	0	0	0	3387	21		3540	3610	0	3682	21	FDL
Clark	Sec. 23	Kin-Ark	Funk	1352	1158 KB	3147	3279	0	0	0	0	3408	10		3553	3619	0	3693	10	FDL
Hardy	Lot 4 (2Q), T. 9, R. 7	Campbell	Fair	1038	900 T	2323	2435	0	0	0	0	2534	0		2618	2688	0	2756	0	GR-N
Hardy	Sec. 24	Amerada	Force	1288	932 KB	2614	2736	0	0	0	0	2845	0		2959	3019	0	3089	0	GR
Mechanic	Sec. 10W	Davis	Weitbrecht	995	1173 DF	2756	2868	0	0	0	0	2980	0		3084	3145	0	3224	0	GR-N
Mechanic	Sec. 12	Allegheny	Raber	1522	991 KB	2799	2927	0	0	0	0	3057	2?	0	3162	3223	0	3295	2?	FDC
Mechanic	Sec. 20W	National	Wager	990	980 KB	2626	2745	0	0	0	0	2856	0		2963	3021	0	3094	0	GR-N
Paint	Sec. 6	Ballard & Cordell	Hersberger	1410	1186 DF	2943	3067	15	0	0	0	3200	17	?	3366	3427	0	3498	32+	GR-D(Shelwell)
Prairie	Sec. 7	Fields	McCurdy	1055	1065 DF	2385	2493	0	0	0	0	2584	0		2664	2737	0	2802	0	GR-N
Prairie	Sec. 33	Parker	Martin	1139	842 DF	2256	2371	0	0	0	0	2468	0		2552	2636	0	2711	0	GR-N
Salt Creek	Sec. 10	Ohio Fuel	Miller	1184	1082 DF	2788	2907	0	0	0	0	3015	25*		3179	3240	0	3313	25*	GR-N
Salt Creek	Sec. 25	Parker & Chapman	Troyer	1283	1314 KB	2994	3119	14*	0	0	0	3243	14*		3402	3470	0	3542	28*	GR-LL-N
Salt Creek	Lot 4, T. 10, R. 6	Kin-Ark	Bowman	1261	1105 DF	2848	2970	0	0	0	0	3074	20		3231	3300	0	3371	20	FDL
Salt Creek	Lot 20, T. 10, R. 6	Parker	Brown	1245	977 DF	2625	2744	0	0	0	0	2855	20?*		3018	3073	0	3145	20?*	GR-N
Walnut Creek	Sec. 5	Kin-Ark	Garber-Miller	1351	1211 KB	3133	3262	20	0	0	0	3410	16*		3580	3658	0	3730	36*	GR-N
JEFFERSON COUNTY																				
Salem	Sec. 32	Gearhart	Miser	353	1127 T	5073	5248	45	20*	12*	55*	5574	80		5871	5970	0	6051	212*	GR-N
LAKE COUNTY																				
Concord	Lot 18, tr. 4	Diamond Alkali	#201 Fee	19	882 GR	2167	2263	76	6	0	0	2447	8	38	2597	2670	57	2829	185	Core desc.
Madison	Lot 1	Timberline	Hejduk	156	685 KB	1816	1911	48	0	0	0	2033	0	30	2163	2233	108*	2423	186	GR-D(Birdwell)
Mentor	Lot 4, tr. 10	Diamond Alkali	Hawgood	3	625 GR	1815	1910	?	?	0	0	2086	?	?	2230	2297	?	2463	?	GR
Mentor	Lot 1, tr. 14	Morton	State of Ohio	22	576 GR	--	--	66	0	0	0	1950	0	20	2093	2155	107	2331	193	Core desc.
Painesville	Lot 15, tr. 4	Diamond Alkali	#231 Fee	115	633 GR	1831	1931	67	36	0	0	2122	0	28	2264	2341	87	NP	218	FDL
Painesville	Lot 20, tr. 4	Diamond Alkali	#304 Fee	105	628 KB	1806	1905	55	17	0	0	2068	0	26	2199	2278	76	NP	174	FDL
Painesville	Lot 49, tr. 4	Diamond Alkali	#204 Fee	33	643 GR	1843	1944	71*	15*	0	0	2125	0	30*	2263	2348	53*	2500	169*	GR-N, ML
Painesville	Fowler Lots	Diamond Alkali	#32 Fee	14	585 GR	--	--	39	32	0	0	?	?	?	2140	?	?	?	71+	Partial core
Perry	Lot 47	Calhio	Calhio	142	701 KB	1863	1958	55*	0	0	0	2102	0	33*	2236	2307	60*	2472	148*	GR, D(Birdwell)
Perry	Lot 89	Diamond Alkali	#202 Fee	20	623 GR	1732?	--	55	0	0	0	1957	0	30	2084	2163	102	2321	187	Core desc.

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft) Top of G unit	Depth (ft) Top of F unit	F salt thickness (ft) F_1	F_2	F_3	F_4	Depth (ft) Top of E unit	E salt thickness (ft)	D salt thickness (ft)	Depth (ft) Top of C unit	Depth (ft) Top of B unit	B salt thickness (ft)	Depth (ft) Top of A unit	Total salt thickness (ft)	Type data
LORAIN COUNTY																				
Avon	Sec. 28	Avon Oil	Kirschenbaum	871	651 KB	1362	1450	59*	0	0	0	1593	5*	21*	1727	1816	48	1968	133*	GR-N
Avon	Sec. 28	Internat. Salt	Farmlands	667	640 GR	1348	--	58	19	0	0	?	5	20	?	?	66	?	168+	Well card data based on a core
Avon	Sec. 28	Internat. Salt	#3 Avon	518	628 GR	1331	--	66	7	0	0	?	?	?	?	?	?	?	73+	Core desc.
Black River	--	Diamond Crystal	City of Lorain	914	591 DF	1044	1132	0	0	0	0	1214	0	10	1324	1407	77	1559	87	GR-N, core
Brighton	Lot 9, tr. 7	Ohio Fuel	Burge	795	887 DF	1296	1395	0	0	0	0	1467	0	0	1572	1655	0	1748	0	GR-N
Brighton	Lot 33, tr. 8	Pure	Fehlon	837	919 KB	1225	1318	0	0	0	0	1395	0	0	1505	1578	0	1672	0	GR-S
Brownhelm	Lot 38	Kapp	Ellison	912	730 KB	1036	1129	0	0	0	0	1206	0	0	1292	1375	19*	1480	19*	GR-N
Camden	Lot 8, tr. 9	Kubat	Lavener	984	872 KB	1218	1308	0	0	0	0	1384	0	0	1488	1573	10	1670	10	D(Eastern)
Carlisle	Sec. 15	Kapp	Spitzer	946	791 KB	1417	1508	35*	0	0	0	1630	11*	22*	1768	1874	18*	1979	86*	GR-N
Eaton	Lot 99	Kapp	Stanislawaski	919	803 KB	1405	1508	?	?	?	?	?	?	?	?	1868	18	1978	18+	pFDL
Grafton	Lot 23	Kapp	Spisak	927	842 KB	1470	1566	57*	5*	0	0	1715	10*	25*	1856	1944	23*	2059	120*	GR-N
Grafton	Lot 56	Great Basins	Maurer	859	885 KB	1563	1659	42	0	0	0	1794	10	23	1930	2023	20	2134	95	FDL
Grafton	Lot 78	Clinton	Mennell	936	866 DF	1538	1635	41	0	0	0	1758	12	16	1908	1991	14	2116	83	FDC
Grafton	Lot 100	Kapp	Toole	910	860 KB	1547	1653	38*	0	0	0	1776	14*	22*	1928	2006	11	2123	85*	pFDL
Henrietta	Lot 8	East Ohio	Born	794	850 DF	1095	1131	0	0	0	0	1224	0	0	1320	1414	0	1509	0	GR-N
Henrietta	Lot 19	East Ohio	Reighley	892	834 KB	1125	1224	0	0	0	0	1300	0	0	1385	1462	3*	1558	3*	GR, pFDL
Henrietta	Lot 24	Kennedy	#1 BSA	897	832 KB	977	1072	0	0	0	0	1149	0	0	1247	1324	0	1415	0	FDC
Henrietta	Lot 100	Kin-Ark	Hasenpflug	908	806 KB	1054	1144	0	0	0	0	1222	0	0	1316	1384	7	1486	7	FDC
Sheffield	Lot 9	Internat. Salt	#2 Sheffield	660	620 GR	1256	--	36	0	0	0	?	0	24	?	?	54+	?	114+	Core desc.
MAHONING COUNTY																				
Beaver	Sec. 5	Columbia	Am. Fire Clay	277	1098 KB	3999	4156	54	28	26	7	4450	21	55	4693	4800	4	4896	195	FDC
Berlin	Lot 18	Atlas	Clark	133	1059 KB	3468	3601	49*	20*	25*	20*	3894	73*		4107	4212	0	4309	187*	GR-N
Berlin	Lot 25	El Paso	Winans	202	1188 KB	3729	3864	66*	23*	25*	13*	4155	73*		4377	4478	5*	4585	205*	GR-LL-N
Ellsworth	Sec. 6	Lenhart & Bennett	Baird	257	1111 KB	3779	3926	74	28	20	6	4224	20	30	4468	4568	0?	4664	178	GR-N-C
Ellsworth	Sec. 19	Belden & Blake	Saybe	213	1063 KB	3580	3723	66	20*	26*	10*	4015	57		4228	4332	4	4432	183*	GR-N, pFDL
Jackson	Lot 32	East Ohio	Barney	221	1050 KB	3511	3656	64	27	31	4	3940	77		4166	4271	7	4367	210	FDL
Jackson	Tr. 13	Atlas	Youngstown Co.	290	1025 KB	3396	3526	84	26	21	25	3835	28	31	4046	4143	9	4251	224	FDC
Smith	Sec. 4	Kin-Ark	Brenner	212	1080 KB	3456	3602	72	29	26	18	3911	66		4132	4236	0	4317	211	FDL
Smith	Sec. 13	Dorfman	Warren	239	1148 KB	3720	3862	75*	29*	22*	24*	4177	66*		4404	4506	0	4587	216*	GR-N
Smith	Sec. 20	East Ohio	Snyder	195	1097 KB	3616	3770	78*	30*	21*	0	4057	46		4272	4381	0	4462	175*	GR-N, pFDL
Smith	Sec. 33	Betz	Zurbrugg	227	1068 DF	3672	3822	75*	29*	16*	5*	4128	44		4351	4455	0	4535	169*	GR-N
Smith	Sec. 36	East Ohio	Ritchie	230	1184 KB	3869	4015	64*	32*	19*	15*	4310	60*		4532	4641	0	4724	190*	GR-N
MEDINA COUNTY																				
Brunswick	Lot 3	Natol	Anderson	1347	1140 T	2243	2350	55*	18*	0	0	2520	0	15*	2665	2755	?	2868	88+*	GR
Granger	Lot 42	Wiser	Warner	1201	1117 KB	2330	2443	60*	40*	0	0	2647	0	20*	2805	2893	0	3003	120*	GR
Guilford	Lot 28	Rixleben	Newcomer	1284	1211 DF	2448	2556	50*	10*	0	0	2708	20*	17*	2880	2922	0	3055	97*	GR-LL-N
Hinckley	Lot 54	Ohio Fuel	Cleveland Tr.	1325	1000 KB	2103	2203	65*	35*	0	0	2418	8*	?	2557	2657	0	2773	108+*	GR-N
Litchfield	Lot 6	Ohio Fuel	Harris	1732	911 KB	1633	1734	28	0	0	0	1850	16	15	1996	2080	11	2200	70	FDC
Medina	Lot 2	Ohio Fuel	Deiss	1296	1105 DF	2232	2336	43*	20*	0	0	2515	18*	19*	2666	2758	6*	2870	106*	GR-N
Sharon	Lot 18	All States	Morris	1588	1164 KB	2445	2557	60*	15*	0	0	2722	11*	15*	2880	2973	0*	3080	101*	GR-LL-N
Sharon	Lot 69	Natol	Shanafeit	1014	1130 T	2529	2343	60*	25*	0	0	2825	18*	15*	3005	3094	0*	3188	118*	GR
Westfield	Lot 10	King	Hawley	1272	1020 T	2028	2132	20*	0	0	0	2250	2*	9*	2400	2484	0	2569	31*	GR-N
Westfield	Lot 31	King	Armbruster	1269	960 T	2050	2155	12*	0	0	0	2262	2*	12*	2407	2505	0	2591	26*	GR-N
Westfield	Lot 57	Ohio Fuel	Reynolds	1293	992 DF	2076	2176	28*	0	0	0	2298	3	13	2475	2560	0	2657	44*	GR-N
York	Lot 4, tr. 2	Ohio Fuel	Huffman	1331	1073 T	2088	2178	40	0	0	0	2325	16*	16*	2472	2576	6*	2688	78*	GR
MONROE COUNTY																				
Jackson	Sec. 18	Penn. RR.	N. Am. Coal	1594	660 KB	6321	6574	0	0	0	96	?	?	?	?	?	?	?	96+	GR-N, core
MORGAN COUNTY																				
Bristol	Sec. 13	Redman	Morris	1177	774 KB	3712	3856	0	0	0	0	4035	0	0	4167	4230	0	4283	0	GR-N

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft)		F salt thickness (ft)				Depth (ft)	E salt thickness (ft)	D salt thickness (ft)	Depth (ft)		B salt thickness (ft)	Depth (ft)	Total salt thickness (ft)	Type data
						Top of G unit	Top of F unit	F_1	F_2	F_3	F_4	Top of E unit			Top of C unit	Top of B unit		Top of A unit		
MUSKINGUM COUNTY																				
Highland	Sec. 1	Camden	King	2248	1189 KB	3607	3741	0	0	0	0	3912	0	0	4054	4118	0	4186	0	D(Shelwell)
Highland	Sec. 23	Western Expl.	Blackstone	2101	996 KB	3425	3550	0	0	0	0	3706	0	0	3836	3898	0	3966	0	GR-N
Monroe	Sec. 23	Quaker State	McCormick	2120	818 KB	3157	3283	0	0	0	0	3440	0	0	3566	3627	0	3694	0	FDC
Union	Sec. 1	Tip Top	Muskingum	2254	978 KB	3506	3634	0	0	0	0	3800	0	0	3930	4000	0	4063	0	GR-N
Union	Sec. 13	Duchscherer	Bricker	2032	1069 DF	3564	3684	0	0	0	0	3842	0	0	3966	4030	0	4091	0	GR-N
Union	Lot 23	Cole	Patton	2028	1086 DF	3666	3784	0	0	0	0	3958	0	0	4081	4148	0	4210	0	GR-N
NOBLE COUNTY																				
Brookfield	Sec. 11	Liberty	Johnson	1395	982 KB	4116	4268	0	0	0	0	4455	0	0	4582	4650	0	4711	0	GR, D(Piper)
Buffalo	Sec. 17	Liberty	Davis	1299	896 KB	3989	4149	0	0	0	0	4351	17		4522	4592	0	4652	17	D(Birdwell)
Buffalo	Sec. 19	Liberty	Tilton	1304	1011 KB	4165	4323	0	0	0	0	4529	11*		4695	4768	0	4829	11*	GR-N
Buffalo	Sec. 33	Southern Triangle	Khune	1324	948 KB	4288	4448	0	0	0	0	4642	10*		4822	4897	0	4958	10*	GR-N
Center	Sec. 25	East Ohio	Guiler	1444	871 KB	4464	4620	0	0	0	0	4845	16	0	5019	5095	0	5161	16	FDC
Elk	Sec. 31	Amerada	Ullman	1278	1035 KB	5284	5478	0	0	0	18	5731	17		5906	5980	0	6040	35	FDL
Jackson	Sec. 10	East Ohio	Brown	1420	922 KB	4568	4746	0	0	0	0	4950	0	0	5086	5160	0	5218	0	FDC
Jackson	Sec. 30	Trico	Deist	1412	924 KB	4459	4613	0	0	0	0	4808	0		4949	5020	0	5072	0	FDC
Noble	Sec. 1	Liberty	Bryan	1298	793 KB	3938	4096	0	0	0	0	4300	11		4462	4531	0	4589	11	D(Allegheny)
Noble	Sec. 12	Liberty	Fulton	1303	946 KB	4114	4273	0	0	0	0	4480	12		4637	4709	0	4766	12	D(Allegheny)
Noble	Sec. 13	Liberty	Hill	1308	878 KB	4107	4265	0	0	0	0	4473	10*		4633	4701	0	4759	10*	GR-N
Noble	Sec. 17	Liberty	DeVolld	1309	833 KB	4122	4284	0	0	0	0	4495	?		4653	4724	0	4783	?	GR-N
Olive	Sec. 16	East Ohio	Ball	1428	1112 KB	4605	4770	0	0	0	0	4978	0		5117	5190	0	5247	0	FDC
Sharon	Sec. 11	Liberty	Foraker	1307	838 KB	4099	4256	0	0	0	0	4441	0		4579	4648	0	4706	0	GR-N
PORTAGE COUNTY																				
Atwater	Lot 16	Atlas	Franks	77	1133 KB	3367	3504	77	38	19	17	3798	43		4001	4099	4	4197	198	GR-LL-N, S-C
Atwater	Lot 105	East Ohio	Wise	484	1172 KB	3276	3404	79	41	19	0	3698	14	31	3900	3995	0	4064	184	FDC
Atwater	Lot 124	East Ohio	Massa	436	1201 KB	3238	3423	86	45	17	0	3702	23	30	3903	4000	0	4074	201	FDL
Atwater	Lot 125	East Ohio	Dornana	476	1169 KB	3296	3421	78	45	17	0	3706	14	30	3891	3991	0	4063	184	FDL
Aurora	Lot 19	McIntire	Tacl	51	1099 KB	2687	2804	?	?	?	0	3063	?	?	3236	3320	0	3410	?	GR-LL
Aurora	Lot 7	Internat. Salt	Ohio #4	24	1000 T	2563	2671	84	65	18	0	2933	14	34	3098	3176	14	3292	229	Core desc.
Brimfield	Lot 11	Cayman	Bauer	479	1112 KB	2887	3012	72	57	13	20	3305	24	30	3490	3588	4	3682	220	FDC
Brimfield	Lot 22	East Ohio	Heichel	40	1098 DF	2843	2963	72*	57*	9*	18*	3253	27*	29*	3440	3530	4*	3619	216*	GR-N
Brimfield	Lot 44	East Ohio	Miller	437	1128 KB	2941	3075	80	69	16	0	3349	21	35	3535	3630	6?	3721	227?	D(Birdwell)
Brimfield	Lot 64	Dusty	Varga	367	1090 T	2980	3107	70*	66*	16*	0	3366	23*	36*	3555	3649	4*	3753	215*	GR-N
Charlestown	Lot 2	East Ohio	Wearly	79	1004 DF	2950	3078	75*	50*	?	12*	3383	14*	28*	3576	3663	8*	3772	262+*	GR-N
Charlestown	Lot 15	East Ohio	Blackman	117	1041 KB	2983	3105	73*	50*	10*	23*	3406	4*	28*	3573	3660	0	3740	188*	GR-N
Deerfield	Lot 13	East Ohio	Grammer	113	1053 KB	3446	3575	66	20*	15*	20*	3895	52		3896	4122	0	4310	173*	GR-N, pFDL
Deerfield	Lot 38	El Paso	Hoffman	191	1056 KB	3380	3515	78*	35*	15*	20*	3821	?	?	4046	4144	0	4229	148+*	GR-N
Deerfield	Lot 43	El Paso	Cherry Federal	203	1046 KB	3313	3462	71*	40*	16*	2*	3749	?	?	3970	4061	?	4155	129+*	GR-N
Deerfield	Lot 49	East Ohio	Courtney	99	1053 KB	3370	3510.	71*	34*	18*	24*	3802	55*		4018	4119	3*	4205	205*	GR-LL-N
Deerfield	Lot 52	Atlas	Armentrout	103	1050 KB	3333	3470	74	34	18	20	3775	50		3984	4095	0	4176	196	GR-LL-N, S-C
Edinburg	Lot 2SW	East Ohio	Kratz	126	1170 KB	3267	3400	73	50	16	0	3677	14	28	3860	3954	2	4037	183	FDL
Edinburg	Lot 2NW	East Ohio	Waltz	61	1058 DF	2994	3118	75*	50*	11*	20*	3424	24*	28*	3624	3717	?	3817	208+*	GR-N
Edinburg	Lot 7	Stocker & Sitler	Pemberton	153	1140 KB	3310	3444	83	49	17	0	3719	14	30	3916	4008	6	4105	199	FDL
Edinburg	Lot 15	East Ohio	Shilliday	125	1103 KB	3119	3241	65*	40*	14*	10*	3526	14	24	3705	3805	4	3897	171*	GR-LL-N, pS-C
Edinburg	Lot 20	Stocker & Sitler	Staron	143	1034 KB	3030	3154	73	54*	16*	6*	3444	14	29	3631	3724	10	3836	202*	GR-LL-N, pS-C
Franklin	Lot 20	Collins	Schlarb	488	1052 T	2806	2914	74	40	7*	15*	3203	18	30	3400	3491	3	3583	188*	GR-pFDC
Freedom	Lot 42	Northern Natural	Wilson	85	1170 KB	3003	3125	80*	50*	15*	0	3405	?	?	3567	3654	?	3766	145+*	GR-N
Freedom	Lot 79	Northern Natural	Moore	68	1198 DF	3025	3150	80*	50*	15*	10*	3461	8*	25*	3630	3723	?	3825	188+	GR-N
Freedom	Lot 94	Pennzoil	Troug	502	1190 KB	3120	3252	81	60	14	5?	3527	12	32	3702	3737	12	3890	216?	FDC
Mantua	Lot 3	Northern Natural	Frost	73	1202 DF	2747	2868	85*	60*	3*	0	3112	?	15*	3262	3332	0	3408	163+	GR
Palmyra	Lot 10-4	Texaco	Bigelow	497	1062 KB	3282	3413	90	34	16	25	3725	24	30	3925	4023	12	4124	231	FDC
Palmyra	Lot 17	Cayman	Myers	468	959 KB	3125	3257	56	43*	10*	0	3549	19*	23*	3745	3843	?	3925	151+*	GR-N
Paris	Lot 28	Cayman	Hauck	467	954 KB	3073	3203	85	38	16	0	3490	25	22	3674	3759	3	3840	189	FDL
Paris	Lot 35	Cayman	Sabol	462	956 KB	3080	3212	74	38	8	0	3503	15	23	3688	3779	4	3860	162	FDL
Randolph	Lot 25	East Ohio	Warner	464	1209 KB	3227	3360	76	53	17	0	3633	19	31	3806	3911	0	3981	196	D(Birdwell)

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft) Top of G unit	Depth (ft) Top of F unit	F salt thickness (ft) F_1	F_2	F_3	F_4	Depth (ft) Top of E unit	E salt thickness (ft)	D salt thickness (ft)	Depth (ft) Top of C unit	Depth (ft) Top of B unit	B salt thickness (ft)	Depth (ft) Top of A unit	Total salt thickness (ft)	Type data
PORTAGE COUNTY (continued)																				
Randolph	Lot 34	Clinton	Brewer	238	1192 KB	3217	3352	69	46	16	0	3626	15	24	3808	3900	0	3970	170	FDL
Randolph	Lot 37	Clinton	Kadikas	282	1132 KB	3114	3246	72	47	17	0	3509	14	23	3691	3779	0	3847	173	FDL
Randolph	Lot 74	Weir	Sayer	220	1186 KB	3186	3316	75*	55*	20*	0	3578	9*	24*	3741	3836	0	3903	183*	GR-N
Randolph	Lot 89	East Ohio	Davis	449	1106 KB	3016	3142	78	50	16	0	3412	20	32	3596	3694	3	3776	199	D(Birdwell)
Ravenna	Lot 7	Kin-Ark	Thornton	214	1097 KB	2845	2964	74	52	11	31	3255	9	26	3413	3486	7	3569	210	FDL
Ravenna	Lot 8	Hinton	Hinman	56	1140 T	2914	3037	72*	54	11*	25*	3333	14*	26*	3507	3587	9*	3630	211*	GR-LL
Ravenna	Lot 27	East Ohio	Kovalevski	64	1071 DF	2922	3044	82*	52*	18*	30*	3362	18*	26*	3549	3642	8*	3742	234*	GR-N
Ravenna	Lot 42	East Ohio	Sprafka	452	1060 KB	2847	2974	82	65	16	20	3282	19	30	3460	3552	12	3651	244	D(Birdwell)
Ravenna	Lot 43	East Ohio	Bidlack	483	1063 KB	2818	2945	84	65	15	23	3260	19	30	3444	3529	8	3628	244	D(Birdwell)
Ravenna	Lot 59S	Atlas	Steele	447	1056 KB	2837	2960	80*	52*	14*	18*	3257	23*	33*	3447	3541	0*	3632	220*	GR-N
Rootstown	Lot 4	East Ohio	Bowers	87	1139 DF	3085	3227	?	?	?	?	3520	?	?	3720	3818	8*	3919	?	GR-N
Rootstown	Lot 14	East Ohio	Bingham	471	1174 DF	3139	3271	79	55	18	3	3537	22	38	3730	3826	8	3927	223	D(Birdwell)
Rootstown	Lot 26	East Ohio	Whittaker	155	1100 KB	3030	3162	65	66	17*	0	3435	18	32	3634	3731	1	3821	199*	GR-LL-N, pFDL
Rootstown	Lot 33	Duty	Barr	301	1098 KB	2947	3069	61	53	17	22	3370	22	34	3560	3660	5	3759	214	FDL
Rootstown	Lot 38	East Ohio	Winkler	433	1086 KB	2984	3114	73	56	17	0	3380	22	35	3572	3669	6	3766	209	D(Birdwell)
Rootstown	Lot 44	East Ohio	Sandy Lake	487	1157 KB	2961	3084	81	58	18	34	3390	22	27	3580	3674	8	3773	248	D(Birdwell)
Shalersville	Lot 30	Northern Natural	Goodell	70	1137 DF	2892	3020	85*	60*	10*	8*	3287	?	?	3460	3550	12*	3670	175+*	GR-N
Suffield	Lot 8	East Ohio	Fedorovich	410	1146 KB	3007	3135	66	50	13	0	3392	11	21	3566	3658	0	3731	161	FDL
Suffield	Lot 15	East Ohio	Ord. Comm.	477	1112 KB	2957	3080	66	56	14	0	3336	21	33	3520	3615	4	3709	194	D(Birdwell)
Windham	Lot 53	Northern Natural	Showalter	76	1100 KB	3022	3147	68*	33*	10*	0	3416	17*	13*	3586	3683	7*	3784	148*	GR-S
Windham	Lot 59	East Ohio	Wheaton	243	933 KB	2919	3047	74*	45*	10*	0	3309	10*	24*	3484	3576	?	3665	163+	GR-N
STARK COUNTY																				
Bethlehem	Sec. 4	East Ohio	Boron	2138	1047 KB	3106	3244	54	24	0	0	3458	41		3656	3736	0	3812	119	D(Birdwell)
Bethlehem	Sec. 17	East Ohio	Gerst	1783	1056 KB	3136	3276	53	13	0	0	3470	37		3671	3754	0	3830	103	FDC
Bethlehem	Sec. 21	Nat. Gas W. Va.	Stansberger	949	980 GR	3113	3253	48*	4*	0	0	3440	23*		3626	3719	0	3800	75*	GR
Canton	Sec. 1	Mustang	Babitt	1373	1098 KB	3359	3504	69	44	8	0	3765	44		3977	4079	0	4162	157	FDC
Canton	Sec. 13	Belden & Blake	Franklin	1169	1070 KB	3357	3501	62	39	0	0	3753	64		3978	4073	0	4156	165	FDL
Canton	Sec. 19	Ashland	Fee	S-877	1069 RT	3267	3409	72	36	0	0	3630	40*		3830	3924	0	4005	148*	GR-N, pS
Canton	Sec. 23	Prudential	Sturrett	1738	1142 KB	3422	3566	74	39	0	0	3805	56		4027	4120	0	4203	169	FDC
Canton	Sec. 25	MB	Mayer	2038	1126 KB	3445	3584	76	39	0	0	3841	48		4055	4153	0	4235	163	FDC
Lake	Sec. 8	Atlas	Price	1039	1141 KB	3070	3197	62*	48	5*	0	3434	26*		3603	3688	0	3757	141*	GR-LL
Lake	Sec. 10	Belden & Blake	Beachy	1048	1181 T	3163	3293	62*	50*	10*	0	3537	32*		3715	3799	0	3873	154*	GR-N
Lake	Sec. 14	Atlas	Kurtz	1060	1171 DF	3202	3327	63	48	13	0	3587	37*		3772	3868	0	3940	161*	GR-LL-N, S-C
Lake	Sec. 16	East Ohio	Troyer	1027	1163 DF	3143	3269	76*	?	0	0	3517	44*		3700	3789	0	3865	120+*	GR-LL
Lake	Sec. 20	Atlas	King	1044	1144 KB	3076	3206	71*	46*	0	0	3453	29*		3633	3720	0	3795	146	GR-LL-N
Lake	Sec. 30	East Ohio	Alloway	1179	1172 KB	3116	3243	75	48	0	0	3478	54		3680	3766	0	3840	177	D(Birdwell)
Lawrence	Sec. 8	East Ohio	Reinoehl	1023	1190 T	2850	2977	38*	6*	0	0	3173	16*		3340	3435	0	3518	60*	GR-N
Lawrence	Sec. 22	East Ohio	Tippel	1020	963 DF	2720	2849	43*	15*	0	0	3031	15*		3193	3284	0	3365	73*	GR-S
Lawrence	Sec. 24	East Ohio	Neidert	2168	962 KB	2775	2905	59	15	0	0	3098	10	10	3260	3338	0	3410	94	GR-D(Birdwell)
Lawrence	Sec. 36	East Ohio	Lindsay	1026	1060 T	2931	3055	54	30*	0	0	3270	16		3421	3496	0	3565	100*	GR-LL-N, pFDL
Lexington	Sec. 12	East Ohio	Court	1124	1061 KB	3480	3622	64	35	17	9	3909	55		4130	4229	2	4318	182	FDL
Marlboro	Sec. 17	Belden & Blake	Westfall	1081	1144 KB	3300	3450	67	53	12	0	3718	43		3916	4022	0	4100	175	FDL
Marlboro	Sec. 19	Ashland	Slusser	1116	11[illegible] KB	3279	3408	74	46	14	0	3678	43		3880	3980	0	4058	177	FDL
Marlboro	Sec. 26	East Ohio	Warner	1072	1162 KB	3433	3575	70*	48*	15*	0	3853	50*		4063	4166	0	4245	183*	GR-N
Marlboro	Sec. 31	Ashland	O'Donahue	1161	1143 KB	3279	3414	67	54	14	0	3685	59		3893	3993	0	4072	194	FDC
Nimishillen	Sec. 7	Mansfield	Hitz	1797	1156 KB	3336	3475	72*	52*	13*	0	3748	54		3950	4051	0	4132	191*	GR-N
Nimishillen	Sec. 31	Belden & Blake	Jacobs	1725	1123 KB	3385	3524	73	52	12	0	3794	51		4000	4102	0	4183	188	FDC
Nimishillen	Sec. 36	Mansfield	Kiko	1294	1198 KB	3662	3815	75*	40*	10*	0	4066	?		4272	3466	0	4448	125+*	GR-N
Osnaburg	Sec. 4	Mustang	Walker	1433	1158 KB	3522	3667	71	42	8	0	3941	56		4160	4258	0	4343	177	FDC
Osnaburg	Sec. 9	Quaker State	Krabill	1622	1128 KB	3571	3720	69	38	9	0	3985	56		4197	4291	0	4373	172	FDC
Osnaburg	Sec. 17	All States	Garaux	1414	1230 KB	3608	3750	64	49	10	0	4018	72		4246	4337	0	4420	195	FDC
Osnaburg	Sec. 19	Belden & Blake	Bennington	1713	1150 KB	3480	3621	63	31	9	0	3883	56		4106	4198	0	4279	159	FDC
Osnaburg	Sec. 21	Texaco	Bechtel	1337	1187 KB	3610	3756	53	49	11	0	4027	57		4251	4347	0	4429	170	FDC
Osnaburg	Sec. 27	Texaco	Clapper	1995	1051 KB	3585	3732	71	40	10	0	3997	54		4218	4312	0	4395	175	FDC

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft)		F salt thickness (ft)				Depth (ft)	E salt thickness (ft)	D salt thickness (ft)	Depth (ft)		B salt thickness (ft)	Depth (ft)	Total salt thickness (ft)	Type data
						Top of G unit	Top of F unit	F_1	F_2	F_3	F_4	Top of E unit			Top of C unit	Top of B unit		Top of A unit		
STARK COUNTY (continued)																				
Paris	Sec. 19	Van Oil	Troescher	1563	1151 KB	3753	3907	60*	35*	5*	0	4168	?		4375	4472	0	4556	100+*	GR
Paris	Sec. 32	Nat. Gas W. Va.	Czekomski	963	1130 T	3824	3974	50*	35*	5*	0	4241	?		4449	4550	0	4633	90+*	GR
Perry	Sec. 28	East Ohio	Cincinat	1024	1060 T	3088	3218	55*	30*	0	0	3436	26*		3623	3704	0	3784	111*	GR-N
Perry	Sec. 30	Belden & Blake	Fringeli	2160	1035 KB	2990	3123	61	25	0	0	3327	21	7	3517	3586	0	3663	114	FDC
Pike	Sec. 1	Refiners	Sickafoose	1839	1116 KB	3540	3684	66	36	0	0	3930	44		4135	4233	0	4314	146	FDC
Plain	Sec. 25	Petrocon	McNurlin	1769	1100 KB	3320	3454	?	?	?	?	3750?	48*		3945	4046	0	4131	48+*	pGR-N
Sandy	Sec. 4	Texaco	Loomis	1989	1060 KB	3547	3697	71	31	5	0	3954	58		4162	4258	0	4341	165	FDC
Sandy	Sec. 5	Mustang	Garaux	1764	1146 KB	3633	3784	65	34	0	0	4034	42		4247	4344	0	4428	141	FDC
Sandy	Sec. 16	Refiners	Pomesky	1881	1005 KB	3618	3772	42	21	0	0	4012	51		4228	4321	0	4401	114	FDC
Sandy	Sec. 18	Texaco	Sickafoose	2041	1158 KB	3615	3770	62	32	0	0	4002	48		4210	4295	0	4376	142	FDC
Sandy	Sec. 20	Belden & Blake	Magnolia	2030	1066 KB	3679	3836	57	27	0	0	4071	39		4283	4378	0	4458	123	FDC
Sandy	Sec. 30	Belden & Blake	Bowman	1145	1029 KB	3548	3717	46	30	0	0	3940	43		4139	4232	0	4311	119	FDL
Sugar Creek	Sec. 11	Belden & Blake	Garl	1329	999 KB	2888	3024	44	19	0	0	3222	25		3407	3477	0	3552	88	FDC
Tuscarawas	Sec. 11	Belden & Blake	Shammo	1181	1064 KB	2905	3034	44	10	0	0	3220	11		3382	3444	0	3516	65	FDC
Washington	Sec. 11	Zenith	King	1113	1295 KB	3802	3955	75*	25*	15*	10*	4249	?		4469	4569	0	4650	125+*	GR-N
Washington	Sec. 12	East Ohio	George	1139	1237 KB	3789	3930	73	28	13	24	4223	54		4443	4546	5	4632	197	FDL
SUMMIT COUNTY																				
Bath	Lot 21	Belden & Blake	Laughlin	292	1175 KB	2453	2544	60*	?	0	0	2762	?	10*	2927	3020	0	3120	70+*	GR-N
Coventry	Lot 4, tr. 15	Diamond Crystal	#51 Fee	447	988 KB	2616	2735	74	29	0	0	2940	26	29	3131	?	?	NP	158+	FDL
Coventry	Lot 10, tr. 2	Diamond Crystal	#17 Fee	367	996 RT	2604	2713	72*	36*	0	0	2916	24*	31*	3126	?	?	NP	163+*	GR-N
Franklin	Sec. 9	Columbia	#31 Fee	349	983 DF	2646	2768	57*	15*	0	0	2927	?	?	?	?	?	?	72+*	GR-N
Franklin	Sec. 17	East Ohio	Cox	314	1060 T	2725	2844	?	?	0	0	3042	?	?	3185	3300	0	3386	?	GR-N
Franklin	Sec. 30	East Ohio	Kusnyir	329	1150 GR	2784	2909	?	25*	0	0	3097	?	?	3265	3358	0	3446	25+*	GR-N
Green	Sec. 15	East Ohio	Groves	348	1210 GR	3026	3147	68	49	0	0	3370	22	?	3524	3602	0	3670	139+	MLL-C, GR, LL
Northhampton	Lot 71	East Ohio	Wheatley	103	910 T	2243	2360	?	?	0	0	2603	?	?	2763	2854	0	2943	?	GR-N
Richfield	Lot 4, tr. 3	Wiser	Bachan	455	1071 KB	--	--	72	51	0	0	2672	15	24	2822	--	13*	3032	175	C
Stow	city	Cuyahoga Falls	city	417	1010 DF	2576	2697	67	46	?	0	2954	?	?	?	?	?	NP	113+	pGR-N
Tallmadge	Lot 6	Brannen	Strietenberger	377	1147 T	2811	2933	59*	62*	14*	0	3209	19*	39*	3404	3506	0	3585	193*	GR-LL-N
TRUMBULL COUNTY																				
Bloomfield	Lot 148	Northern Natural	Frandrich	13	904 KB	2687	2800	83	28*	0	0	3014	7*	23*	3167	3251	42*	3347	183*	GR-LL-N, S
Gustavus	Lot 77	Northern Natural	Runkle	15	1141 KB	2996	3110	74*	12*	0	0	3308	7*	34*	3468	3557	51*	3688	178*	S
Gustavus	Lot 82	Am. Minerals	Clisby	23	950 KB	2848	2960	78	8	0	0	3148	9	38	3313	3404	54	3540	187	FDC
Hartford	Lot 25	Dinger	Blaney	12	1204 GR	3538	3667	?	?	0	0	3917	?	?	3917	4110	?	4316	?	GR-N
Hubbard	Lot 29	Bowman	Lackwasky	18	990 T	3705	3839	72*	26*	15*	0	4117	15*	29*	4306	4410	13*	4519	170*	GR-LL
Lordstown	Lot 38	Atlas	Loudon	36	965 KB	3148	3273	80	23	20	21	3574	25	31	3769	3873	8	3970	208	FDC
Lordstown	Lot 77	Atlas	Campbell	28	1043 KB	3313	3444	84	27	19	11	3739	27	29	3944	4044	11	4143	208	FDC
Mesopotamia	Lot 48	Northern Natural	Wengerd	16	1038 KB	2633	2744	77*	28*	0	0	2957	5*	22*	3117	3198	47*	3321	179*	GR-S
Vernon	Lot 12	Smith	Allen	17	926 KB	3020	3146	82*	8*	0	0	3370	8*	30*	3538	3640	40*	3744	168*	GR-LL-N, S
TUSCARAWAS COUNTY																				
Auburn	Sec. 18W	Quaker State	Miller	1060	1120 KB	3275	3408	7	0	0	0	3550	21		3723	3796	0	3871	28	FDC
Clay	Lot 7, Gnaden-hutten Tr.	Stocker & Sitler	Keffer	965	997 KB	3621	3769	9	0	0	0	3941	26		4129	4204	0	4281	35	FDL
Dover	Lot 27	East Ohio	Kane	1155	1057 KB	3454	3596	36	0	0	0	3772	44		2972	4051	0	4130	80	FDL
Dover	Lot 33	Quaker State	Helwig	1102	1197 KB	3678	3828	19	0	0	0	4006	46		4217	4298	0	4373	65	FDC
Dover	3Q, T. 9, R. 2	Cyclops	Reeves	1410	896 KB	3382	3525	25*	0	0	0	3704	45		3910	3973	0	4052	70*	GR-N
Fairfield	Sec. 10	MB	Burton	1573	953 KB	3620	3770	38	18	0	0	3991	49		4206	4294	0	4373	105	GR-D(Piper)
Franklin	Lot 7, T. 9, R. 3	Mansfield	Kohr	1178	1013 KB	3186	3324	39	6	0	0	3494	27		3667	3750	0	3824	72	D(Shelwell)
Goshen	Lot 39, Schoen-brunn Tr.	East Ohio	Cross Creek	1067	.887 KB	3605	3750	21	0	0	0	3936	36		4140	4217	0	4295	57	FDC
Jefferson	Sec. 18	East Ohio	Urfer	1110	1003 KB	3480	3600	6	0	0	0	3755	29		3949	4015	0	4085	35	FDC
Lawrence	Sec. 14	Quaker State	Froman	1080	1084 KB	3302	3443	46	12	0	0	3634	39		3827	3910	0	3986	97	D(Birdwell)
Lawrence	Sec. 15	Quaker State	Wallick	1056	1063 KB	3234	3380	41	7	0	0	3564	41		3564	3780	0	3920	89	FDC
Lawrence	Sec. 16	Collins	Harper	1186	978 DF	3219	3362	40	0	0	0	3536	29		3729	3804	0	3884	69	FDC
Lawrence	Lot 71, Zoar Tr.	Nat. Gas W. Va.	Streb	512	1073 DF	3425	3562	?	?	0	0	3758	?		3956	4041	0	4120	?	GR
Lawrence	Lot 112, Zoar Tr.	Status	Wassem	671	950 T	3438	3583	?	?	0	0	3783	?		3982	4067	0	4148	?	GR-N

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft) Top of G unit	Depth (ft) Top of F unit	F salt thickness (ft) F_1	F_2	F_3	F_4	Depth (ft) Top of E unit	E salt thickness (ft)	D salt thickness (ft)	Depth (ft) Top of C unit	Depth (ft) Top of B unit	B salt thickness (ft)	Depth (ft) Top of A unit	Total salt thickness (ft)	Type data
TUSCARAWAS COUNTY (continued)																				
Mill	Sec. 29	Collins	Duso	1617	1153 KB	4222	4387	12	5	3	0	4603	28		4808	4882	0	4959	48	FDC
Mill	Lot 12, Spencer Tr.	Appalachian	Gundy	1161	962 KB	3798	3936	19	10	0	0	4161	42		4382	4457	0	4536	71	D(Eastern)
Oxford	Sec. 20	Everly	King	1192	926 KB	3651	3799	0	0	0	0	3981	31		4172	4241	0	4310	31	D(Shelwell)
Perry	Sec. 15	Stocker & Sitler	Hayden	1486	1221 KB	4189	4345	10*	0	0	0	4535	?		4734	4807	0	4884	10+*	GR-N
Rush	Sec. 3	Collins	Evans	1618	914 KB	3809	3968	8	5	0	0	4162	38		4374	4449	0	4526	51	FDC
Rush	Sec. 25	Stocker & Sitler	Huebner	1030	1221 KB	4075	4230	10*	10*	0	0	4429	30*		4632	4704	0	4769	50*	GR-N
Salem	Sec. 8	Western Expl.	Buck	1164	862 KB	3383	3530	0?	0*	0	0	3692	10		3860	3931	0	4000	10?*	GR-N
Sandy	Lot 6(1Q)	Mustang	Nixton	1051	1028 KB	3510	3660	50*	30*	0	0	3889	33*		4094	4183	0	4260	113*	GR-N
Sandy	Lot 10, Bimeler Subdiv.	Status	Sattler	676	990 T	3554	3700	?	?	0	0	3918	?		4117	4208	0	4281	?	GR-N
Sugar Creek	Sec. 21	Natl. Assoc.	Borntrager	794	1031 KB	3193	3322	25*	0	0	0	3481	?		3662	3741	0	3818	25+*	GR-N
Union	Sec. 27	Atlas	Scalia	966	901 KB	3892	4048	18*	12*	2*	0	4272	45*		4492	4571	0	4650	77*	GR-N
Union	Sec. 32	Collins	True	1251	859 KB	3832	3993	18	13	2	0	4222	28		4443	4525	0	4606	61	FDC
Warren	Sec. 32	Atlas	Edwards	875	1122 KB	3945	4103	30*	14*	0	0	4320	37*		4526	4603	0	4683	81*	GR-LL-N
Warwick	Sec. 1	East Ohio	Berlandis	1032	1042 KB	3760	3904	17	0	0	0	4094	23		4287	4365	0	4444	40	FDC
Warwick	2Q, T. 7, R. 1	East Ohio	Natoli	1084	868 KB	3614	3763	18	0	0	0	3953	31		4159	4236	0	4314	49	FDC
Warwick	2Q, T. 7, R. 1	Resources	Lint	1181	850 KB	3636	3790	19*	2*	0	0	3986	?		4196	4271	0	4350	21+*	GR-N
Warwick	3Q, T. 7, R. 1	Wynn	McClean	1158	845 KB	3629	3791	17	8	0	0	3985	32		4189	4266	0	4341	57	D(Birdwell)
Warwick	Lot 3	Collins	Everett	1163	854 DF	3607	3764	16	0	0	0	3947	25		4140	4215	0	4293	41	FDC
Warwick	Lot 8	Collins	Kinsey	1132	921 DF	3647	3794	18	0	0	0	3980	24		4173	4251	0	4328	42	FDC
Washington	Lot 4(2Q)	Collins	Hunt	1353	1087 DF	3867	4014	0	0	0	?	4192	23		4382	4461	0	4524	23+	FDC
York	Sec. 14	East Ohio	Johnson	977	1159 KB	3734	3887	15	0	0	0	4063	30		4259	4324	0	4401	45	FDL
WASHINGTON COUNTY																				
Adams	Lot 29SW	Berry	Offenberger	3272	949 KB	4653	4815	0	0	0	0	5012	0		5151	5223	0	5277	0	FDC
Independence	Sec. 10	Penn Gas	Knowlton	D-1	1001	--	6250*	0	0	0	>50*	?	?		?	?	0	6960	50+*	Sample log
Lawrence	Sec. 15	Guernsey	Matheny #2	3310	651 KB	5330	5515	?	?	?	58	5820	0		5989	6067	0	6127	58+	FDC
Liberty	Sec. 20	Great Lakes	Scott	1914	904 DF?	5410	--	?	?	?	?	?	?		6000	?	0	6165?	?	Sample log
Liberty	Sec. 31	Eastern Operating	Gebike	3306	901 KB	--	5552?	?	?	?	?	5733	21		5916	5994	0	6050?	21+	FDC
WAYNE COUNTY																				
Baughman	Sec. 9	East Ohio	Weygandt	1334	1068 KB	2600	2722	46	3	0	0	2890	17		3050	3150	0	3234	66	GR-LL-N, S-C
Baughman	Sec. 14	East Ohio	Shisler	900	1074 DF	2703	2826	36*	10*	0	0	2982	20*		3156	3250	0	3331	66*	GR-N
Baughman	Sec. 25	Ohio Fuel	Eberly	1188	1031 DF	2720	2845	45*	22*	0	0	3040	20*		3210	3298	0	3381	87*	GR-N
Canaan	Sec. 9	McBride	Whitmire	843	1065 T	2131	2244	10*	0	0	0	2346	15*		2496	2589	0	2676	25*	GR-N
Canaan	Sec. 12	Lincoln	Romich	898	993 T	2122	2234	35*	0	0	0	2365	?		2516	2611	0	2700	35+*	GR-N
Canaan	Sec. 22	Wehmeyer	Fetzer	966	1100 T	2235	2338	19*	0	0	0	2455	22*		2618	2711	0	2791	41*	GR-S
Canaan	Sec. 25	Kin-Ark	Zook	1377	1071 KB	2266	2376	25	0	0	0	2497	36		2682	2774	0	2850	61	FDL
Canaan	Sec. 32	Martin	Armstrong	940	1180 T	2340	2444	0	0	0	0	2531	?		2682	2782	0	2861	?	FDL
Canaan	Sec. 35	Obermiller	Mensching	511	1140 T	2375	2478	15*	0	0	0	2588	?		2755	2845	0	2922	15+*	GR-N
Chester	Sec. 15	Sun	Martin	1434	1210 KB	2295	2402	0	0	0	0	2490	?		2603	2687	0	2765	?	GR-N
Chippewa	Sec. 34	East Ohio	Dawson	560	1042 DF	2576	2699	40*	5*	0	0	2875	22*		3043	3142	0	3221	67*	GR-LL
Clinton	Sec. 12	Arrowhead	Bergoon	847	890 DF	2143	2260	0	0	0	0	2345	0		2445	2512	0	2590	0	GR-N
Congress	Sec. 36E	Schultz	Ewing	1031	1043 T	2128	2227	0	0	0	0	2312	10*		2462	2544	0	2621	10	GR-LL
East Union	Sec. 10	Heyser	Yoder	833	1184 KB	2706	2830	30*	0	0	0	2951	20*		3110	3199	0	3284	50*	GR-LL
East Union	Sec. 23	Natol	Hackett	1153	1124 DF	2700	2820	30*	0	0	0	2950	5*		3102	3190	0	3272	35*	GR-N
Franklin	Sec. 21	Vanson	Piant	795	1015 DF	2460	2550	0	0	0	0	2648	0		2733	2815	0	2887	0	GR-N
Franklin	Sec. 23	Wenner	Hostetler	1543	1098 DF	2556	2650	0	0	0	0	2746	0		2826	2898	0	2966	0	FDC
Franklin	Sec. 33	Natol	Mast	1149	920 T	2287	2405	0	0	0	0	2497	8		2628	2708	0	2786	8	FDL
Green	Sec. 4	Ohio Fuel	Indermuhle	1316	1164 KB	2478	2590	27*	0	0	0	2723	15*		2870	2965	0	3048	42*	GR-N
Green	Sec. 6	Wehmeyer	Hohenshil	979	1110 T	2389	2496	19	0	0	0	2621	28		2789	2880	0	2957	47	GR-S, MLL-C, GR-LL
Green	Sec. 8	Gower	Schrock	1398	1128 KB	2432	2545	27	0	0	0	2676	31		2842	2933	0	3013	58	FDL
Green	Sec. 19	Great Lakes	Ramseyer	1466	1139 KB	2506	2618	21*	0	0	0	2743	25*		2914	2994	0	3076	46*	GR-N

APPENDIX B.–SUMMARY OF CONTROL WELL DATA–Continued

Township	Land subdivision	Operator	Name	Permit number	Elevation at wellhead (ft above sea level)	Depth (ft)		F salt thickness (ft)				Depth (ft)	E salt thickness (ft)	D salt thickness (ft)	Depth (ft)		B salt thickness (ft)	Depth (ft)	Total salt thickness (ft)	Type data
						Top of G unit	Top of F unit	F_1	F_2	F_3	F_4	Top of E unit			Top of C unit	Top of B unit		Top of A unit		
WAYNE COUNTY																				
Milton	Sec. 8	Natl. Assoc.	Miller	801	972 KB	2181	2289	50*	0	0	0	2435	23*		2595	2692	0	2780	73*	GR-N
Milton	Sec. 11	Morton	Wilson	1126	970 T	2312	2423	50*	0	0	0	2565	?		?	?	0	NP	50+*	
Milton	Sec. 18	Muth	Conrad	1128	1040 DF	2239	2343	35*	0	0	0	2474	26*		2634	2735	0	2816	61*	GR-N
Milton	Sec. 22	Storey	McConnell	945	965 KB	2288	2401	53	0	0	0	2544	37		2722	2820	0	2899	90	GR, MLL-C
Milton	Sec. 30	Kin-Ark	Gasser	1379	1044 KB	2234	2342	27	0	0	0	2464	31		2635	2729	0	2806	58	FDL
Paint	Sec. 24	Ponderosa	Miller	1638	1023 DF	2878	3010	?	?	0	0	3154	?		3347	3420	0	3494	?	GR-N
Plain	Sec. 6	Acitelli	Guenther	834	1100 T	2134	2240	0	0	0	0	2328	?		2454	2532	0	2610	?	GR-N
Plain	Sec. 12E	Admiral	Strock	1062	1050 T	2275	2388	0	0	0	0	2478	12*		2611	2691	0	2774	12	GR-N
Plain	Sec. 25E	Kubat	Sanger	1169	1074 DF	2274	2384	0	0	0	0	2482	?		2607	2684	0	2761	?	GR-N
Salt Creek	Sec. 10	Sanders	Swartzentruber	814	1181 T	2785	2906	0	0	0	0	3013	5*		3122	3204	0	3275	5	GR-N
Salt Creek	Sec. 21	Ohio Fuel	Petershiem	1229	1152 DF	2745	2866	0	0	0	0	2966	0*		3079	3158	0	3225	0	GR-N
Sugar Creek	Sec. 13	Wiser	Withrich	708	1220 T	2980	3106	45*	0	0	0	3279	15*		3443	3522	0	3604	60*	GR-N
Wayne	Sec. 2	Atlas	Yates	1314	1140 KB	2427	2538	9	0	0	0	2639	25		2800	2884	0	2960	34	FDL
Wayne	Sec. 17	Vanson	Boreman	894	1166 DF	2353	2456	?	0	0	0	2560	15*		2711	2794	0	2871	15+*	GR-N
Wooster	Sec. 18	Phillips	Stockdale	790	970 T	2254	2360	?	0	0	0	2459	10*		2602	2680	0	2761	10+*	GR-N
Wooster	Sec. 21	Vanson	Koorn	793	855 DF	2218	2336	0	0	0	0	2430	10*		2575	2657	0	2737	10*	GR-N
WEST VIRGINIA																				
HANCOCK COUNTY																				
Clay Dist.		Humble	Minesinger	80	1052 KB	5240	5418	29	12	12	120	5839	43		6022	6136	0	6220	216	FDL
MARSHALL COUNTY																				
Clay Dist.		Solvay #3	Round Bottom	241	635	6205	?	?	?	?	120	Average of six wells from drillers' logs							120+	GR
Franklin Dist.		Pitts. Plate Glass	Marshall	523	648 DF	6509	6718	0	0	0	127*	7110	74*		7349	7440	0	7509	201*	GR-N
Liberty Dist.		McCormick	Burley	539	1435 KB	8332	8546	0	0	0	0	8781	48		9115	9264	0	9340	48	FDC
PLEASANTS COUNTY																				
Grants Dist.		Commonwealth	Kerns	667	1085 KB	4900	--	0	0	0	0	?	?		?	?	0	5885	?	FDC
Grants Dist.		Holtom	Dillon	646	669 KB	4980	--	0	0	0	0									FDC
						Restored G top by interval from top Bass Islands; did not reach E salt level														
RITCHIE COUNTY																				
Grant Dist.		Benedum	Rinehart	--	830? DF	--	6523	?	?	?	80*	?	?		?	?	?	--	80+*	Sample desc.
Grant Dist.		Adena	Metz	3242	832 KB	6140	6353	?	?	?	40	0	No log below 6560 feet						40+	GR-N
TYLER COUNTY																				
Union Dist.		FMC 1	Bens Run	262	645 KB	6105	?	?	?	?	85	Average of six wells from drillers' logs							85+	
WOOD COUNTY																				
Walker Dist.		Hope	Sandhill	351	1050? DF	4660	6407	0	0	0	0	6640	0		6826	6909	0	6960?	0	GR-N, samples
						Restored G top; compared with interval from top of "Big Lime" in Adena #1 Metz, an unfaulted well														
PENNSYLVANIA																				
CRAWFORD COUNTY																				
Beaver		Imperial	Shadeland	8	932 DF	2442	2534	0	0	0	0	2624	0?	25*	2763	2834	45*	2954	70?*	GR-N
Conneaut		McClusky	Carter		1120 DF	2683	2779	20*	0	0	0	2902	0	25*	3060	3130	55*	3270	100*	GR-LL
Summerhill		Benedum	Kardosh	7	1337 KB	3073	3173	?	?	?	?	3302	?	?	3455	3540	?	3690	?	GR-LL-N
Summerhill		Trans American	Reynolds	64		2775	2876	34*	?	0	0	3007	4*	32*	3169	3243	55*	3376	125+*	GR-N
ERIE COUNTY																				
Conneaut		McConnell	Borst	86	974 KB	2373	2465	0	0	0	0	2535	?	?	2640	2720	?	2847	?	GR-N
Conneaut		Cayman	Boothby	325	828? DF	2088	2179	0	0	0	0	2247	?	?	2351	2407	?	2524	?	GR-N
Conneaut		Cayman	Nesbit	220	674 DF	1823	1915	0	0	0	0	1987	?	?	2078	2137	?	2253	?	GR-N
MERCER COUNTY																				
Pymatuning		Melben	McKnight	4	960 KB	3410	3540	?	?	?	?	3765	?	?	3950	4045	?	4152	?	GR-N

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS

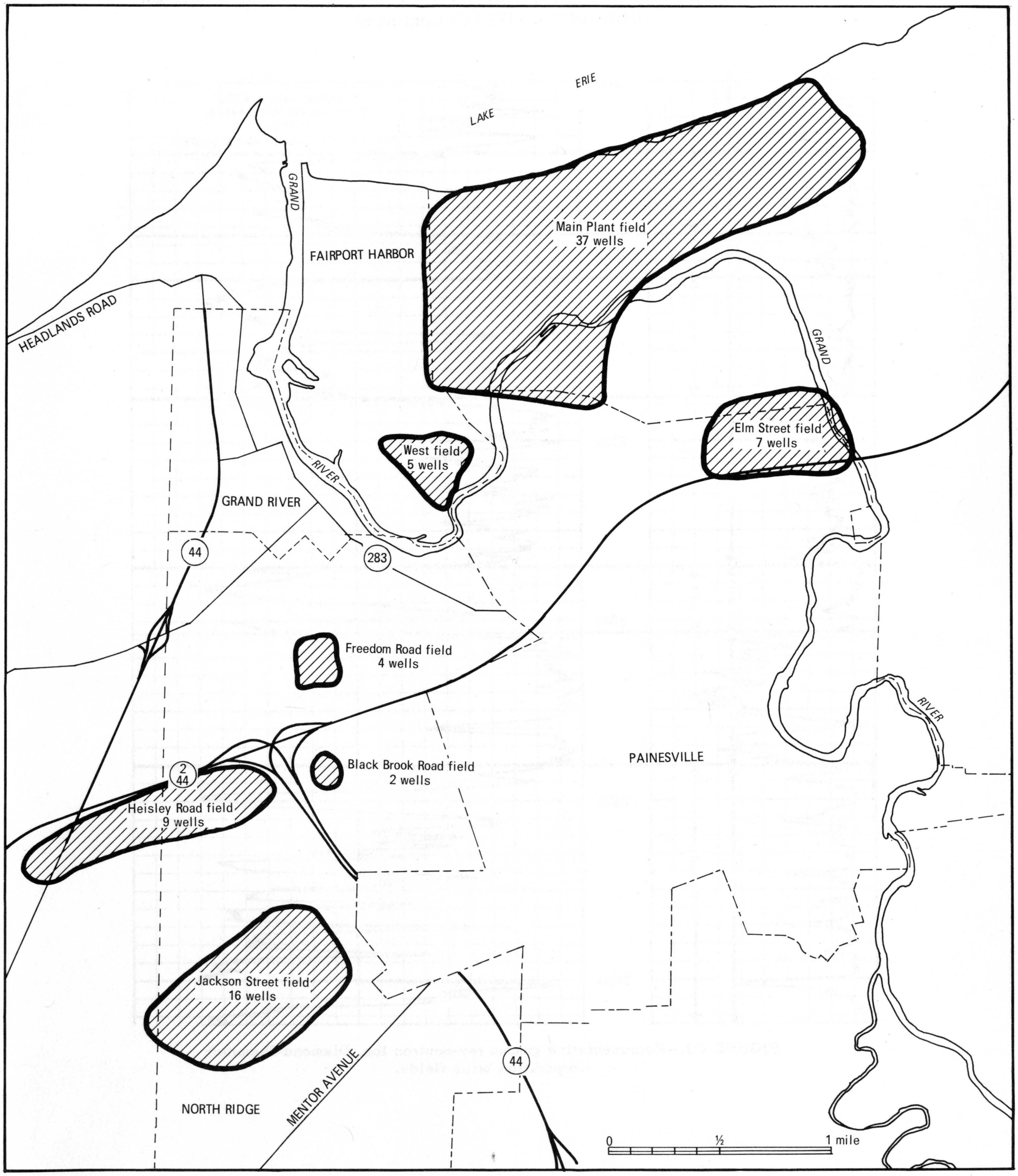

FIGURE C1.–Diamond-Shamrock Corporation brine fields, Painesville Township, Lake County, Ohio.

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

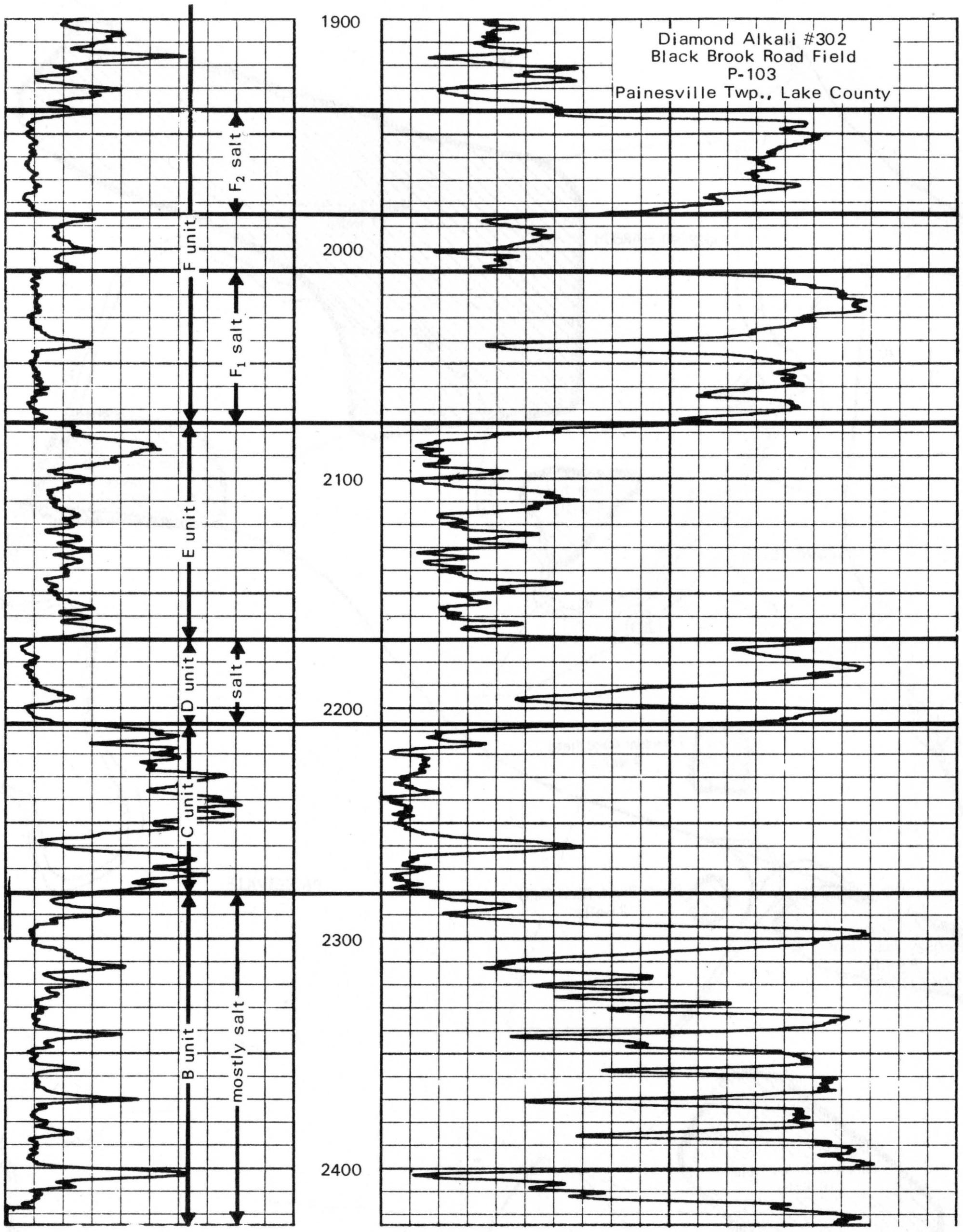

FIGURE C2.–Representative gamma ray-neutron log, Diamond-Shamrock Corporation brine fields.

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

TABLE C1.–*Diamond Shamrock brine field, Painesville, Painesville and Mentor Townships, Lake County*

Well	Permit or identification number	Land subdivision	Township map identification number	Date drilled	Date plugged	Field	Remarks
Painesville							
Diamond Alkali #1	84PP	Fowler Lots	--		Sept. 1960	Main Cavity	
#2	--	Lot 3, tr. 3	L-233			Main Cavity	
#3	--	Fowler Lots	--			Main Cavity	
#4	D-26	Fowler Lots	L-235			Main Cavity	
#5	--	Lot 3, tr. 3	L-236			Main Cavity	
#6	83PP	Fowler Lots	L-237		June 1960	Main Cavity	
#7	--	Lot 3, tr. 3	L-238			Main Cavity	
#8	--	Lot 2, tr. 3	L-239			Main Cavity	
#9	--	Lot 2, tr. 3	L-240			Main Cavity	
#10	135PP	Lot 2, tr. 3	L-241		Apr. 1970	Main Cavity	
#11	D-25	Fowler Lots	L-242			Main Cavity	Logs
#12	D-24	Lot 2, tr. 3	L-243			Main Cavity	
#13	D-23	Lot 2, tr. 3	L-244			Main Cavity	
#14	D-4	Lot 2, tr. 3	L-95			Main Cavity	Logs
#15	D-22	Lot 2, tr. 3	L-245		July 1971	Main Cavity	Logs
#16	--	Lot 2, tr. 3	L-110			Main Cavity	
#17	--	Lot 2, tr. 3	L-246	1929		Main Cavity	
#18	--	Fowler Lots	L-247			Main Cavity	
#19	--	Lot 2, tr. 3	L-248			Main Cavity	
#20	139PP	Lot 1, tr. 3	L-249		Aug. 1970	Main Cavity	
#21	34, D-3	Lot 2, tr. 3	L-97			Main Cavity	Logs
#22	--	Lot 3, tr. 3	L-250			Main Cavity	
#23	D-2	Fowler Lots	L-96		June 1971	Main Cavity	Logs
#24	69PP	Lot 1, tr. 3	L-251		Mar. 1958	Main Cavity	Logs
#25	D-20	Lot 1, tr. 3	L-252			Main Cavity	Logs
#26	137PP	Lot 1, tr. 3	L-253		June 1970	Main Cavity	Logs, D-19
#27	D-18	Lot 1, tr. 2	L-254			Main Cavity	
#28	D-16	Lot 1, tr. 2	L-255			Main Cavity	
#29	D-17	Lot 1, tr. 2	L-256			Main Cavity	
#30	61PP	Lot 1, tr. 2	L-257		Jan. 1957	Main Cavity	
#31	D-15	Fairport	L-258	1929		West	Logs
#32	14	Fowler Lots	L-100	Jan. 1953	Feb. 1963	West	Logs, S-565
#33	134PP	Lot 6, tr. 3	L-259	1935	Mar. 1970	Main Cavity	Logs, D-14
#34	D-13	Fairport	L-260	1929	May 1971	West	Logs
#35	D-12	Lot 7, tr. 3	L-261			Main Cavity	Logs
#36	112PP	Fowler Lots	L-262		Apr. 1969	Elm Street	
#37	133PP	Lot 4, tr. 3	L-263		Mar. 1970	Elm Street	Logs, D-7
#38	132PP	Lot 5, tr. 3	L-264		Feb. 1970	Elm Street	Logs, D-8
#39	D-18	Lot 1, tr. 2	L-98	1943		Main Cavity	Logs, S-298
#40	130PP	Lot 5, tr. 2	L-265		Feb. 1970	Elm Street	D-9
#41	113PP	Fowler Lots	L-266	Oct. 1957	Apr. 1969	Elm Street	D-10
#42	114PP	Fowler Lots			Apr. 1969	Elm Street	D-11
#43	D-6	Fowler Lots	L-268	1946	June 1971	Main Cavity	Logs
#44	D-5	Fowler Lots	L-269		May 1971	Main Cavity	Logs
#45	D-27	Lot 3, tr. 3	L-270		July 1971	Main Cavity	Logs

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

TABLE C1.–*Diamond Shamrock brine field, Painesville, Painesville and Mentor Townships, Lake County*–Continued

Well	Permit or identification number	Land subdivision	Township map identification number	Date drilled	Date plugged	Field	Remarks
#46	15, 131PP	Fowler Lots	L-271	Aug. 1953	Feb. 1970	Elm Street	Logs, S-619
#47	24	Fairport	L-272	1954	Feb. 1963	West	Logs
#48	31	Fairport	L-273	Apr. 1955	Sept. 1963	West	Logs
#121	95	Lot 56, tr. 4	L-93	Feb. 1963		Jackson Street	Logs
#122	96	Lot 56, tr. 4		Feb. 1963		Jackson Street	
#123			No record			Jackson Street	
#124	80	Lot 57, tr. 4		Feb. 1960		Jackson Street	Logs
#125	81	Lot 56, tr. 4		Apr. 1960		Jackson Street	Logs
#126	93	Lot 57, tr. 4		Oct. 1961		Jackson Street	Logs
#132	42-1	Lot 51, tr. 4	L-88	Dec. 1955		Jackson Street	Logs
#133			No record			Jackson Street	
#134	42-3	Lot 56, tr. 4	L-90	Jan. 1956		Jackson Street	Logs
#135	45	Lot 56, tr. 4	L-91	Feb. 1956		Jackson Street	
#141	46	Lot 50, tr. 4	L-89	Apr. 1956		Jackson Street	Logs
#142			No record			Jackson Street	
#143	54	Lot 50, tr. 4	L-87	Apr. 1956		Jackson Street	Logs
#144	82	Lot 49, tr. 4		Mar. 1960		Jackson Street	
#145	46	Lot 56, tr. 4	L-93	Mar. 1956		Jackson Street	Logs
#151	53-1	Lot 49, tr. 4	L-92	June 1956		Jackson Street	Logs
#152	53-2	Lot 50, tr. 4	L-274	May 1956		Jackson Street	Logs
#153	53-3	Lot 49, tr. 4	L-275	June 1956		Jackson Street	Logs
#203	32	Lot 15, tr. 4	L-85	Oct. 1955		Heisley Road	Logs (core test?)
#204	33	Lot 49, tr. 4	L-94	Apr. 1955		Jackson Street	Logs (core test?)
#205	35	Lot 51, tr. 4	L-84	July 1955		Jackson Street	Logs (core test?)
#206	58	Lot 6, Fairport	L-276	Oct. 1956	Mar. 1958	Not a brine well	Logs (core test?)
#301	102	Lot 17, tr. 4		Aug. 1966		Black Brook Road	Logs
#302	103	Lot 17, tr. 4		Aug. 1966		Black Brook Road	Logs
#303	104	Lot 20, tr. 4		Dec. 1966		Black Brook Road	Logs
#304	105	Lot 20, tr. 4		Dec. 1966		Black Brook Road	Logs
Diamond Shamrock #221	109	Lot 14, tr. 4		May 1968		Freedom Road	Logs, S-2157
#222	110	Lot 14, tr. 4		May 1968		Freedom Road	Logs
#231	115	Lot 15, tr. 4		Aug. 1969		Heisley Road	Logs
#232	116	Lot 15, tr. 4		July 1969		Heisley Road	Logs
#241	117	Lot 15, tr. 4		July 1969		Heisley Road	Logs
#242	118	Lot 15, tr. 4		June 1969		Heisley Road	Logs
#251	119	Lot 15, tr. 4		Apr. 1969		Heisley Road	Logs
Mentor							
Diamond Shamrock #252	120	Lot 4, tr. 10		June 1969		Heisley Road	Logs
#261	121	Lot 4, tr. 10		May 1969		Heisley Road	Logs
#262	122	Lot 4, tr. 10		May 1969		Heisley Road	Logs

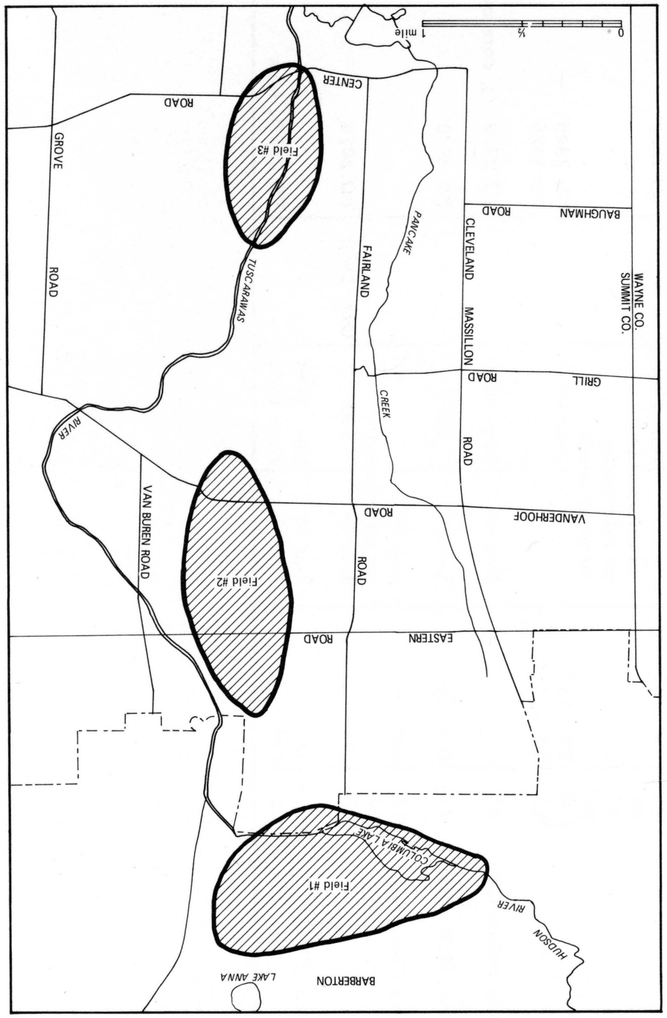

FIGURE C3.–Pittsburgh Plate Glass Company, Columbia Southern Chemicals Division, brine fields, Franklin and Norton Townships, Summit County, Ohio.

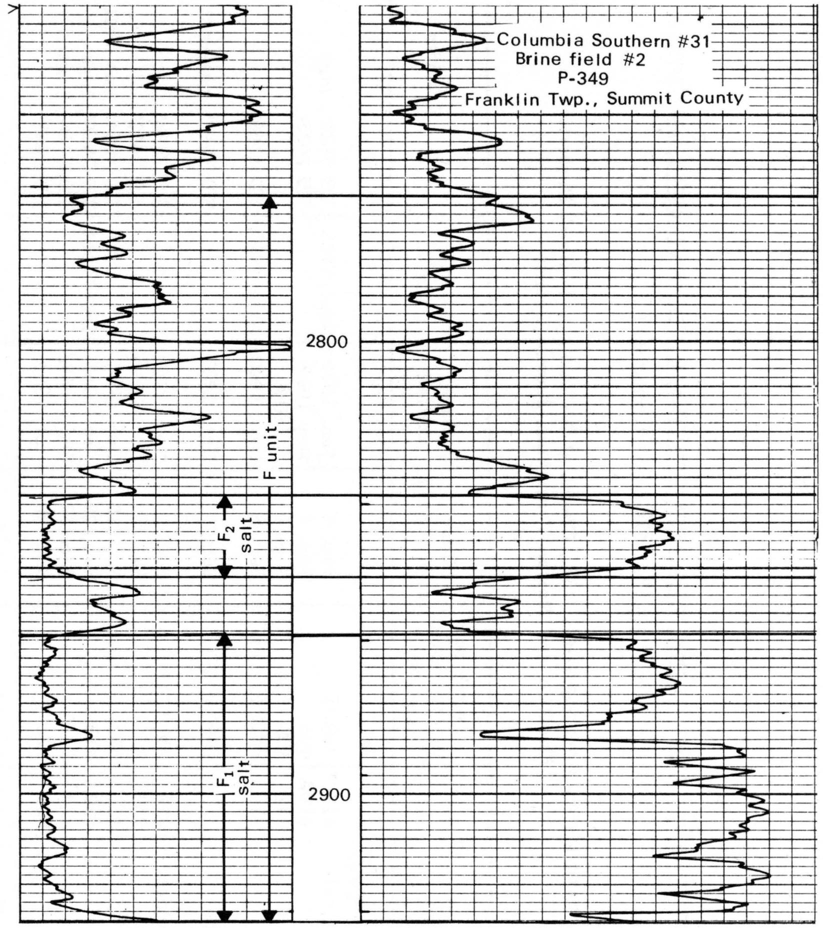

FIGURE C4.–Representative gamma ray-neutron log, Pittsburgh Plate Glass Company, Columbia Southern Chemicals Division, brine fields.

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

TABLE C2.–*PPG Industries, Inc., Chemical Division, brine field, Barberton, Franklin and Norton Townships, Summit County*

Well		Permit or identification number	Land subdivision	Date drilled	Date plugged	Remarks
Franklin Twp.						
Columbia Chemical	#19	399PP	Sec. 4	Jan. 1929	Sept. 1963	TD 3920', logs
	#19A	406	Sec. 4	May 1965		TD 2935'
	#9	WW 1736	Sec. 8	1900		
	#20	341PP, 1737	Sec. 8	Dec. 1929	Nov. 1957	TD 3095'
Columbia, Barber		B-0041-2-1	Sec. 9	Nov. 1927		TD 3942', gas well
Columbia Chemical	#18	WW 1727	Sec. 9	Nov. 1927		TD 3934'
	#31	349	Sec. 9	Mar. 1959		TD 2932'
	#30	333	Sec. 16	Oct. 1957		TD 3964', gas well
	#22A	418	Sec. 20	Jan. 1947	Sept. 1966	TD 2936', logs
	#24	D-16	Sec. 20	Sept. 1942		TD 2936', logs
	#29	221	Sec. 20	Apr. 1955		TD 2941'
Norton Twp.						
Columbia Chemical	#1	WW 1733		Sept. 1899		TD 3006'
	#2	392PP	Lot 77	Apr. 1900	Oct. 1962	TD 2848'
Southern Alkali	#4	191		Dec. 1899	July 1951	TD 2889'
	#5	WW 1735		Apr. 1900		TD 2850'
	#6		no information			
	#7		no information			
	#8		no information			
	#10	WW 1732		July 1900		TD 2846'
	#11	WW 1731				TD 3425'
Columbia (PPG) CT	#3		Lot 64	Dec. 1939		TD 2819'(?), core no. 955
Columbia, McFrederick	#1	OFG 311	Lot 75	1913		TD 3870'
Columbia Chemical	#13	309	Lot 78			
	#14		no information			
	#15	216	Lot 78	1907	Oct. 1956	TD 2874'
Columbia (PPG)	#21A	411	Lot 98	Nov. 1965		
	#32	438	Lot 76	Aug. 1968		TD 2867', logs

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

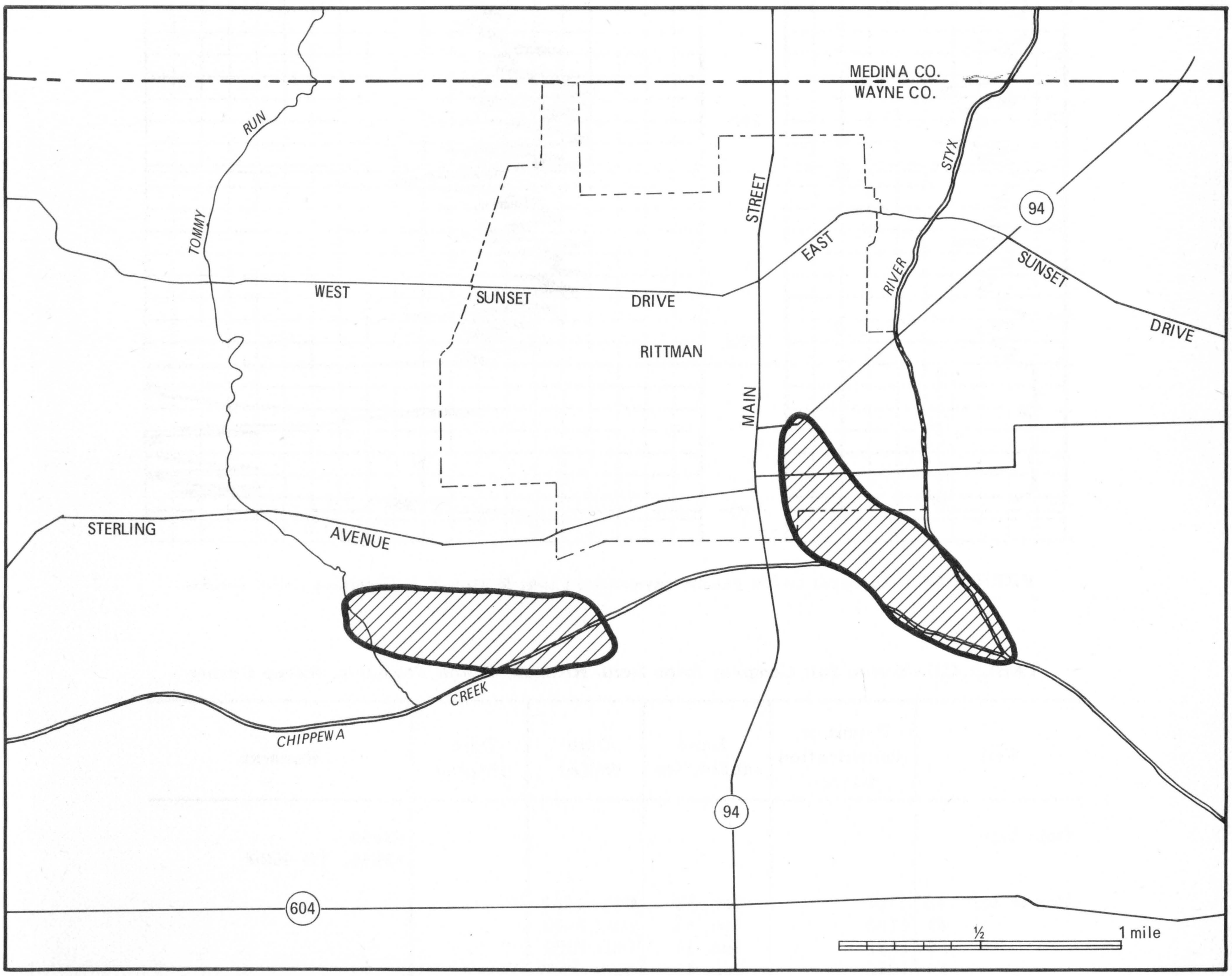

FIGURE C5.–Morton Salt Company brine fields, Milton Township, Wayne County, Ohio.

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

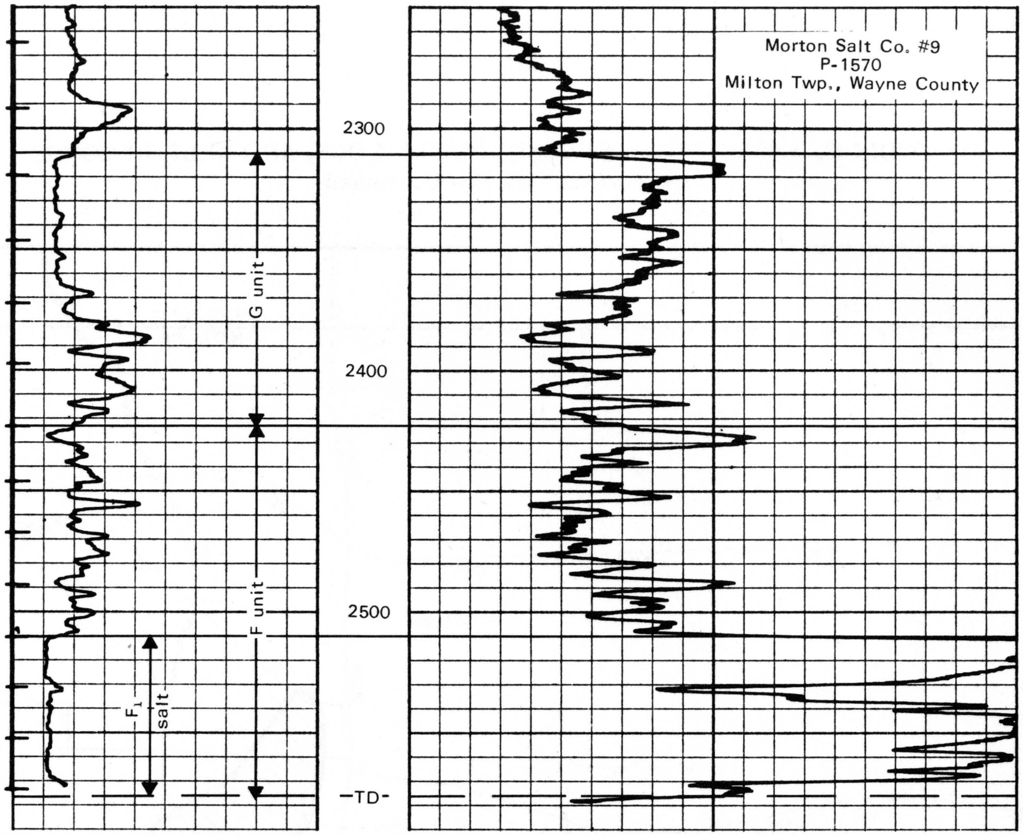

FIGURE C6.–Representative gamma ray-neutron log, Morton Salt Company brine fields.

TABLE C3.–*Morton Salt Company brine field, Rittman, Milton Township, Wayne County*

Well	Permit or identification number	Land subdivision	Date drilled	Date plugged	Remarks
Ohio Salt					#3953 #3946, TD 4600'
Morton Salt #3	1167	Sec. 10	Feb. 1961		
#1	1126	Sec. 11	Oct. 1960		
#2	1127	Sec. 11	Oct. 1960		
#4	1210	Sec. 11	June 1961		
Ohio Salt #1	B-0051-3-15	Sec. 12	Feb. 1935		Show of gas in Clinton
#2	B-0051-3-9	Sec. 12	Nov. 1937		Clinton gas well
Morton Salt #15	1253PP	Sec. 12	Nov. 1930	June 1962	
#12	1253PP	Sec. 12	Jan. 1931	June 1962	
#17	1253PP	Sec. 13	July 1940	Sept. 1961	
#18	1253PP	Sec. 13	Nov. 1948	June 1962	
#6	1348	Sec. 14	June 1963		
#7	1349	Sec. 14	May 1963		
#8	1350	Sec. 14	June 1963		
#9	1570	Sec. 14	Jan. 1970		
#5	1347	Sec. 15	May 1963		

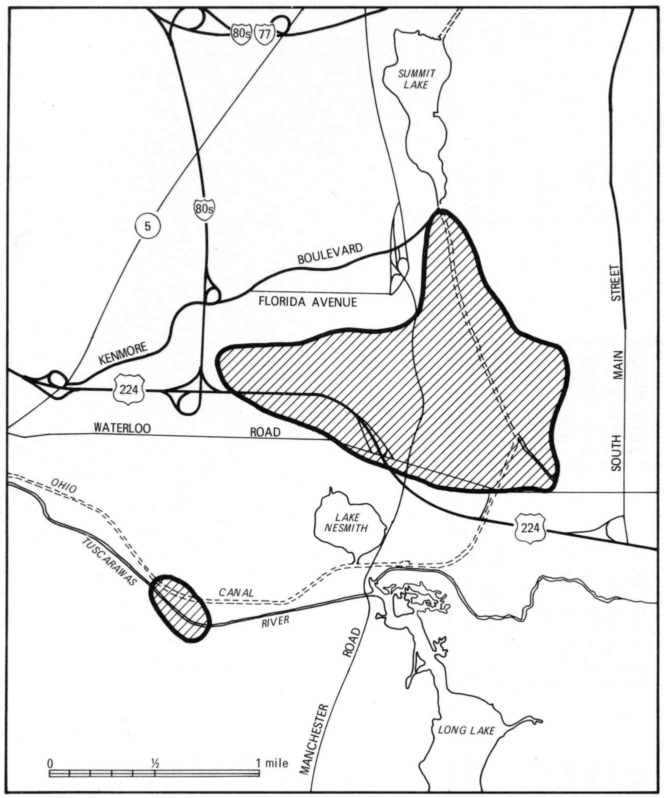

FIGURE C7.—Diamond Crystal Company brine fields, Akron (Kenmore), Coventry Township, Summit County, Ohio.

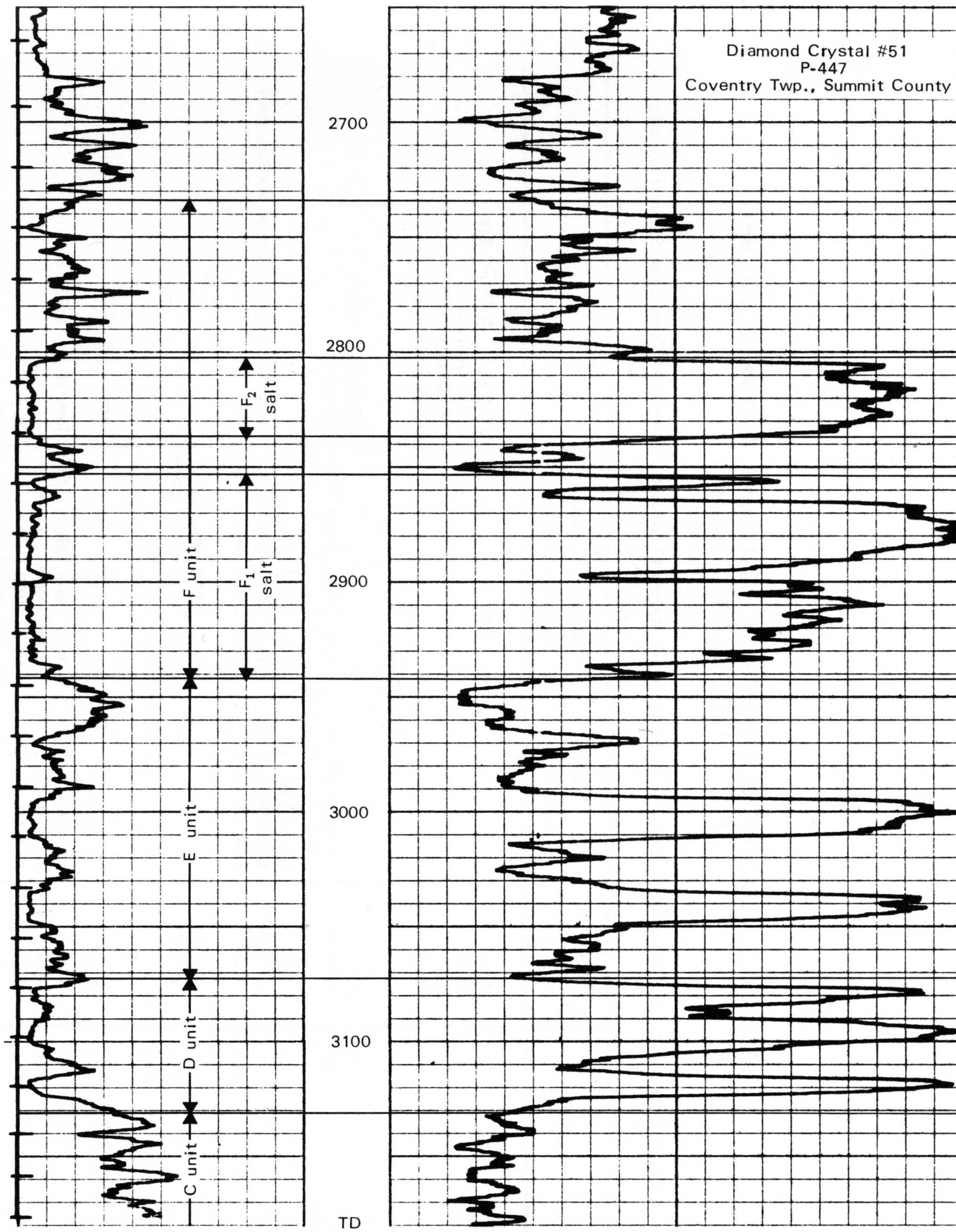

FIGURE C8.—Representative gamma ray-neutron log, Diamond Crystal Company brine fields.

APPENDIX C.–LOCATIONS, REPRESENTATIVE LOGS, AND WELL RECORDS FOR BRINE FIELDS–Continued

TABLE C4.–*Diamond Crystal Salt Company brine field, Akron (Kenmore), Coventry Township, Summit County*

Well		Permit or identification number	Land subdivision	Date drilled	Date plugged	Remarks
Colonial Salt	#1	3951		1901?		TD 2903', drillers' log
	#2	3950				USGS Bull. 669
	#3	3949				USGS Bull. 669
	#4	3948				USGS Bull. 669
	#5	no information				
	#6	3947				USGS Bull. 669
	#7	396PP	1½ mile NW of Schwartz Corners	Aug. 1911	June 1923	TD 2861'
	#8	375PP	Lot 17, tr. 10	Dec. 1911	Dec. 1961	
	#9	381PP	Lot 10(?), tr. 2	Jan. 1912	Sept. 1961	Sample no. 435, may be Medina gas well
	#10	376PP	Lot 13, tr. 2	July 1918	Apr. 1962	
	#11	384PP		Dec. 1920	May 1963	
	#12	435PP		Feb. 1921	Sept. 1968	
	#13	no information				
Diamond Crystal	#14	230	Lot 38, sec. 18	Nov. 1954		Sample no. 647
	#15	308	Tr. 11	Sept. 1956		
	#16	366	Lot 10, tr. 2	Mar. 1960	May 1965	Sample no. 865, logs
	#16A	405	Lot 10, tr. 2	Aug. 1964		
	#17	367	Lot 10, tr. 2	Mar. 1960		Logs
	#18	371	Lot 10, tr. 2	July 1960		Logs
	#19	370	Lot 10, tr. 2	June 1960		Logs
	#20	387	Lot 10, tr. 2	July 1962		Logs
	#21	388	Lot 10, tr. 2	July 1962		
	#22	397	Lot 10, tr. 2	June 1963		Logs
	#50	443	Lot 4, tr. 15	Feb. 1969		Logs
	#51	447	Lot 4, tr. 15	Mar. 1969		Logs

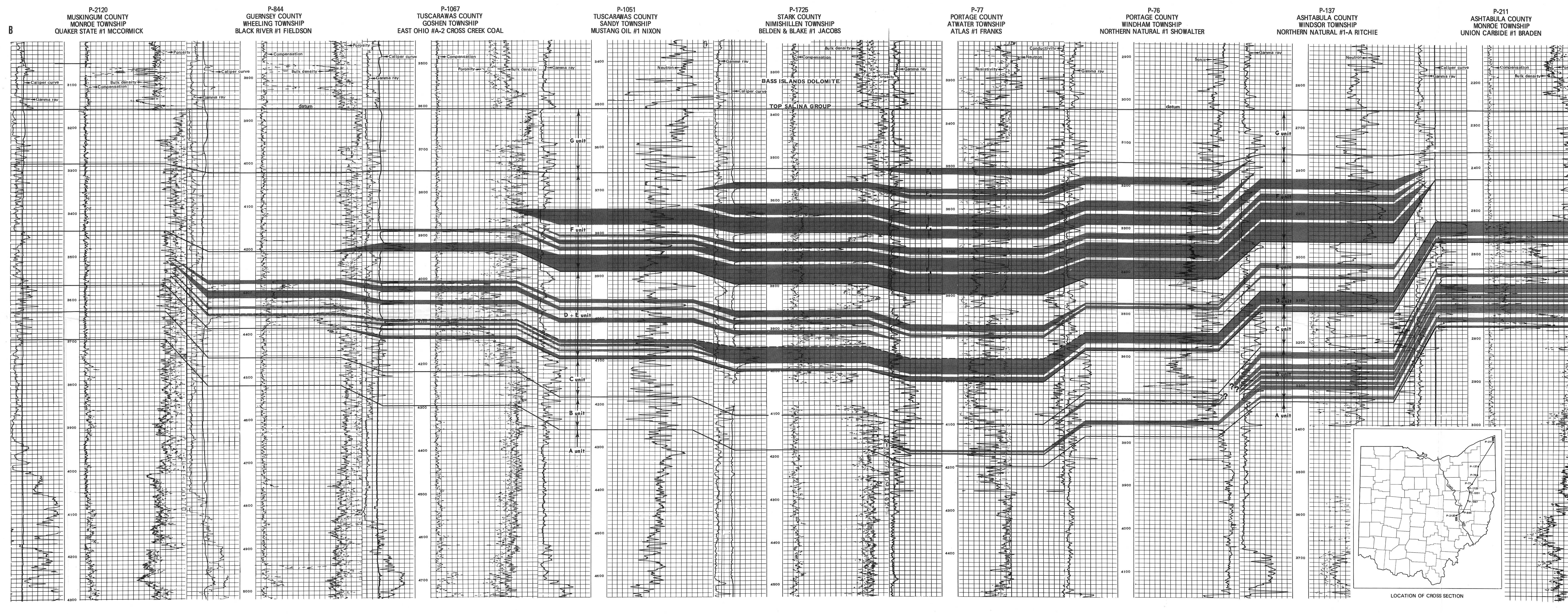

Plate 1.–Log cross sections

Plate 2.–Structure on top of A unit

P-1278 Permit or map number
-5005 Elevation of A unit (feet below sea level)

Structure contour, drawn on top of A unit, *contour interval 100 feet (except in portions of adjoining states), dashed where control is poor*

Core information available for entire Salina section

Core information available for part of Salina section

Well having geophysical log that permits accurate reading of salt thickness (density or caliper log)

Well having geophysical log from which salt thickness has been interpreted directly

Well not drilled through entire Salina section; not logged

Well not drilled through entire Salina section; logged

Well not drilled through entire Salina section; partially logged

NA Information not available

X Well for which only sample information is available

A–A′, B–B′ Locations of cross sections shown on plate 1

10 0 10 20 MILES
SCALE 1:500,000

Plate 3.–Structure on top of G unit

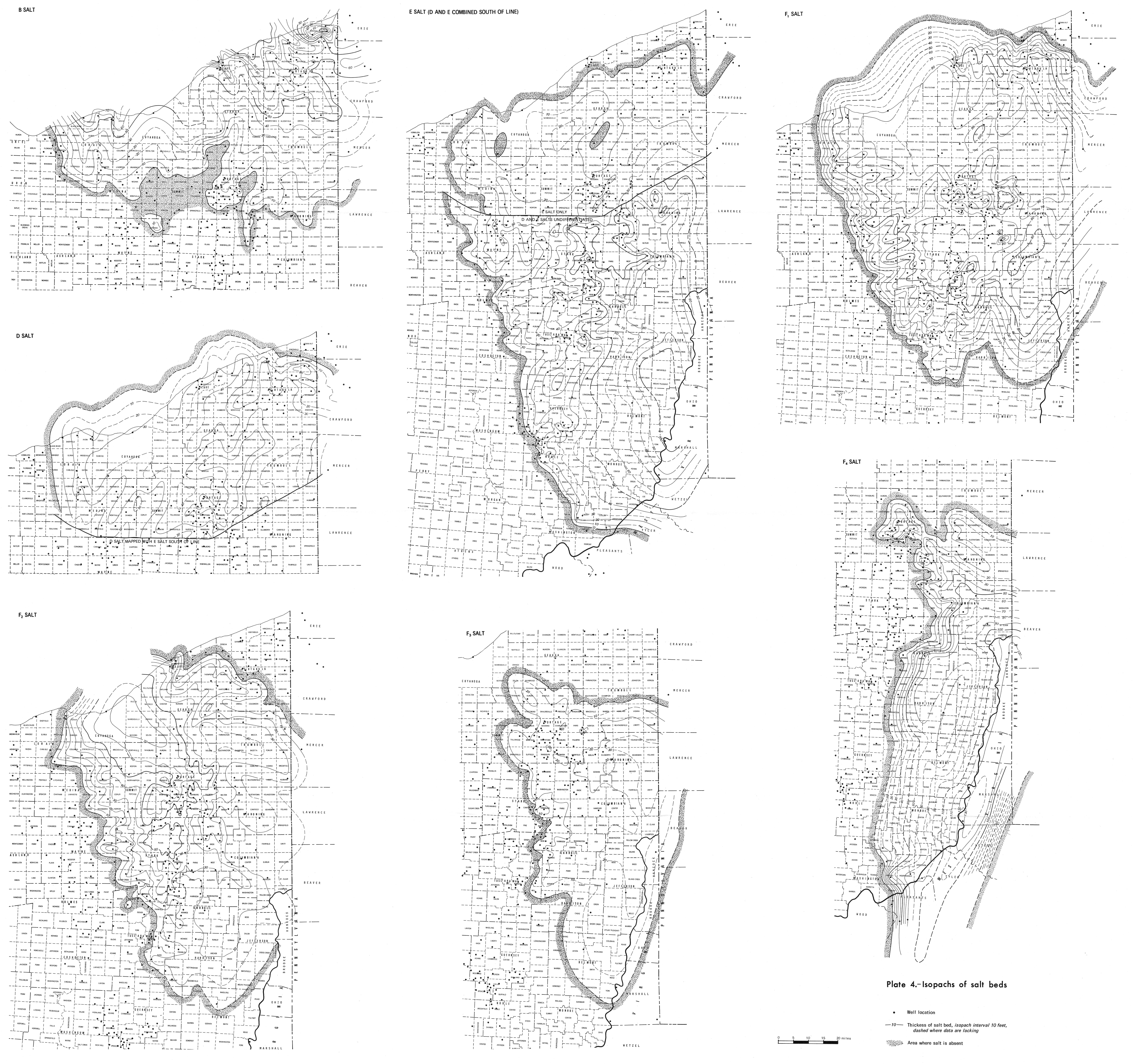

Plate 4.–Isopachs of salt beds

- • Well location
- —10— Thickness of salt bed, *isopach interval 10 feet, dashed where data are lacking*
- Area where salt is absent